APPH 226:
Detail and Distortion

Objectives:

5.5 Discuss the effect that geometric factors have on diagnostic quality

MRT Program

Radiographic Quality

- How would you describe a high-quality radiograph?
  - A radiograph that accurately reproduces structures and tissues as they are in actuality
  - Does the image truly represent the anatomy with accuracy?

Factors

- What are the four factors that affect radiographic image quality?
  - Photographic – a balance between radiographic:
    - Density
    - Contrast
  - Geometric
    - Detail (increase detail)
    - Distortion (decrease distortion)

Definitions

- Recorded detail:
  - Degree of sharpness or distinctness of structural lines on a radiograph

- Radiographic image quality is determined by the ability of an image to demonstrate structures

Descriptors of Detail

- Recorded detail
- Definition
- Sharpness
- Blur
- Resolution

Resolution

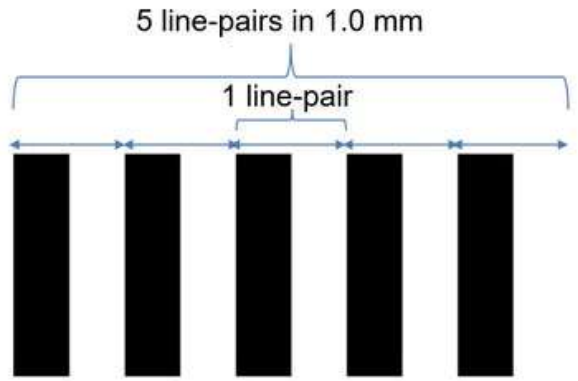
- Defined as:
  - The ability of the imaging system to resolve or distinguish between two adjacent structures
  - How recorded detail is measured and expressed
  - Expressed in line pairs per millimeter
    - Lp/mm

Resolution

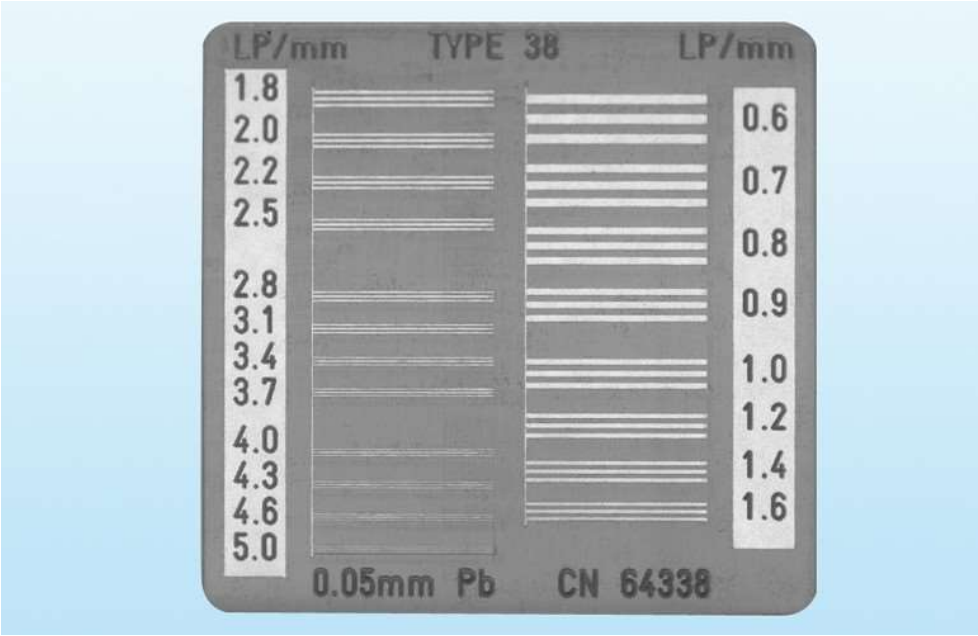
- Is a combination of spatial and contrast resolution
- Spatial Resolution
  - The ability to image small objects with high subject contrast
  - The smallest object that can be seen/visualized
    - i.e. microcalcifications
- Contrast Resolution
  - The ability to distinguish objects with similar subject contrast
    - i.e. liver and spleen

Line Pairs and Test Pattern

- Consist of the line and the space
- Line pair = line + space



https://coldharboursupply.com/blogs/news/tube-selection-and-specs-a-beginners-guide



https://quart.de/en/products/test-phantoms/resolution-patterns/line-pair-patterns

Resolution – Test Pattern

- Device used to record and measure line pairs
- Line pairs per millimeter test is used to assess image quality
- Describes the spatial resolution of the imaging system
- Spatial resolution – ability to differentiate 2 side-by-side (adjacent) structures
- Indicates how many pairs of contrasting lines can fit within one millimeter, line pairs per millimeter (lp/mm)
- The more line pairs visualized, the higher the resolution and recorded detail
- Demonstrates how the imaging system resolves fine details

Detail

- Controlled by three factors
  - Geometric unsharpness
  - Motion unsharpness
  - Image receptor unsharpness

Geometric Unsharpness

- Factors that affect geometric unsharpness are:
  - Focal spot size
  - Distance
    - OID
    - SID

Focal Spot Size

- Normally ranges from 0.1 to 3.0 mm
- Focal spot size affects the detail

Focal Spot Blur

- Occurs because the actual focal spot is not a point source
  - Rectangular source
- Blurred region on radiograph is a result of the focal spot having size
- Undesirable

Focal Spot Blur

- Most important factor for spatial resolution
- High contrast structures that are smaller than the focal spot blur cannot be imaged
  - Cannot visualize the object if it is smaller than the blur

Focal Spot Blur

- Geometric relationships that govern magnification will influence blur
- If conditions are altered to increase magnification on the image, focal spot blur will also increase
  - In the interest of minimizing focal spot blur, these conditions should be avoided whenever possible
    - With increased OID/magnification, focal spot blur will also increase

Focal Spot Blur

- To decrease the effects of focal spot blur, and increase recorded detail:
  - Smallest focal spot possible
  - SID as large as possible
  - OID as small as possible

SID

- Just as radiation intensity changes when the SID is altered, so does the amount of unsharpness recorded on the image
- Due to divergence properties of the x-ray beam
  - Geometric relationship exists with x-ray source, object and image receptor

SID

- When SID is increased, image unsharpness decreases which results in:
  - Increased image detail
- With a longer SID, the diverging rays become more perpendicular to the object, that is what decreases the unsharpness

OID

- Also affects the unsharpness of the image
- When the exit beam leaves the patient, it continues to diverge
  - If given more distance to diverge, more unsharpness will occur
- The most optimal situation would be if the OID = 0
- This is impossible in diagnostic imaging

OID

- Distance between area of interest and image receptor (OID) has the greatest effect on the amount of geometric unsharpness recorded
  - More than SID or focal spot size
  - This is a factor that can be controlled by the technologist to a certain degree
- For optimal results, try to minimize OID as much as possible

Geometric Unsharpness

- Minimizing unsharpness is important, but the effects of these variables must be considered
- A small focal spot
  - Not suitable for all exams, especially large parts
- Large large focal spot
  - Not practical for many exams
  - Increase in radiographic technique to compensate

Motion Unsharpness

- The most detrimental effect on resultant image
- Includes motion of:
  - Anatomy, part or patient
  - Tube
  - Image Receptor

Patient Motion

- Blur
- The most disadvantageous factor to maximizing recorded detail
  - Motion artifacts are almost all a result of patient motion
- Can be voluntary or involuntary
  - Voluntary – within the patient's control
    - Example – suspend respiration
  - Involuntary – outside of the patient's control
    - Example - heartbeat

Patient Motion

- Sometimes the patient is unable to stop moving
  - E.g. Tremors, trauma, intoxication
- What are other methods that a technologist can use to try and control/minimize motion artifacts on the image?
  - Short exposure times
  - Communication
  - Immobilization devices

Other causes of Motion

- Less typical, but motion unsharpness can also be caused by equipment
- Motion from tube, table or image receptor
  - Highly unlikely
  - Equipment has locks
    - Defective equipment, ineffective/damaged locks, not engaged in a lock

Image Receptor Unsharpness

- Unsharpness as recorded onto the image receptor
- Advances in technology have helped to decrease the amount of exposure required to produce an image with appropriate radiographic density

Film/Screen System – old technology

- Factors that affect recorded detail:
- Screen properties
  - Phosphor size
  - Phosphor layer thickness
  - Phosphor concentration
  - Reflective layer
- Film Screen contact

Phosphor Size

- Large phosphor size results in the information being spread out and will decrease recorded detail

Screen Speeds and Unsharpness

- With higher speed screens, less exposure is required to achieve appropriate density on the IR

Film Screen Contact

- Film is sandwiched between two intensifying screens
- If there is a space between the screen and the film, it creates an area of unsharpness due to divergence of light
- Wire mesh test used to determine appropriate contact between film and screen(s)

Digital Receptors (DR) and Resolution

- Primary factors that affect the resolution of all types of digital imaging systems are:
  - Geometric properties of the IR
  - Image processing system

Intensifying layer with CR

- Limitations for recorded detail are similar to that of film/screen
- Factors that limit detail are:
  - Phosphor size
  - Layer thickness
  - Concentration
  - Scanning of the screen and processing

Resolution and CR

- Scanning of the screen and processing phase
  - Laser scans the Imaging Plate (IP), which emits light upon stimulation
  - Finely focused laser correlates to about one pixel dimension
  - The smaller the pixel, the higher the resolution
  - Laser beam determines the resolution

Direct Digital Radiography (DR)

- Uses a photoconductor made of amorphous selenium and a Thin Film Transistor (TFT)array
- DR image receptor consists of a matrix of detector elements - DELs
- The x-ray beam is **directly** converted to an electrical signal
- Analog-to-Digital converter changes analog signal to digital signal to produce the digital image on the viewing monitor
- Limited by the size of the detector element

Indirect Digital Radiography (DR)

- Indirect DR first converts x-rays into light photons and then into an electrical signal
- Indirect DR can use charge-coupled device (CCD) system or Thin Film Transistor (TFT)system
- Both have a scintillation layer made of either cesium iodide or gadolinium
- Scintillation layer converts x-rays into light photons, CCD sensor chips convert the light photons into electrical signals
- TFT system have additional layer, the photodiode, made of amorphous selenium. Photodiode converts light photons into an electrical signal that is transferred to the TFT array
- Electrical signals are then sent by an Analog-to-Digital Converter which sends the converted digital signal to a computer for processing

DR Resolution

- Image processing system sets a limit on recorded detail/spatial resolution
- Depends on:
  - Matrix size = 1 MP to 5 MP (High Res)
  - Pixel size – 1000 x 1000 to 2000 x 2500
  - Grey Scale – bit systems
    - 8 bit – 256 greys
    - 10 bit – 1046 greys
    - 14 bit – 16 384 greys
    - 16 bit – 65 536 greys

Distortion

- Results from radiographic misinterpretation of an object
  - Can be size or shape
    - Size distortion
      - Magnification
    - Shape distortion
      - Elongation
      - Foreshortening

Technologist's Responsibilities

- Distortion is directly related to positioning
- Can minimize distortion with careful attention to:
  - Distances
  - Central Ray
  - Patient position
  - Image Receptor (IR) position

Size Distortion

- Defined as:
  - A variation in the size of an object's image as compared to its actual size
- In radiography, images are always magnified in comparison to their true size
  - Due to presence of OID
- SID and OID play a key role in how size distortion is affected

OID

- Directly related to magnification
- Out of all the factors, has the greatest effect on magnification
- When taking radiographs, creating a 2-dimensional image from a 3-dimensional object
- Some parts will have more OID than other parts

SID and Magnification

- As SID is increased, magnification decreases
  - Due to the divergence of the beam
- If the straighter rays (closer to the central ray) are creating the image, they are more perpendicular to the part
  - Less magnification

Magnification

- In some cases, it is done intentionally
  - Magnification views
  - Digital – can be done with post processing
- For the most part, it is undesirable and should be minimized as much as possible

Shape Distortion

- When a radiograph misrepresents an object with distortion of its shape
- Two forms
  - Elongation
    - Image appears longer than actual object
  - Foreshortening
    - Image appears shorter than actual object

Shape Distortion

- Can occur from:
  - Inaccurate alignment of the x-ray beam to detector
  - Inaccurate alignment of the x-ray beam to body part
  - Inaccurate alignment of the body part to detector

- Any misalignment of the above factors will result in distortion of the body part on the resultant image
  - *Central Ray also affects distortion (must be centered accurately to the body part)

Shape Distortion

- Sometimes used intentionally for better visualization of anatomy
- Generally, shape distortion is not desirable

Shape Distortion

- Object Thickness
  - OID changes across the object
  - More distortion with a thick object vs a thin one
- More magnification over areas with more OID
- Angling the tube could "throw" anatomy differently on the image
  - Can be used to advantage
    - Helps reduce superimposition of anatomy

Shape Distortion

- Object shape also contributes to shape distortion
- The more irregular the shape, the more distortion will occur
  - Important to have two perspectives for most exams (e.g. AP and Lateral)
- Due to beam divergence and OID
- Ideally to minimize the shape distortion from object shape, would be an object that is in the same shape as the diverging beam

Minimizing Shape Distortion

- To minimize shape distortion, ensure proper alignment of:
  - X-ray tube
  - Part
  - Image Receptor
  - Entry/Exit point of the CR (Central Ray)

Readings

Radiologic Science for Technologists

- Pg. 163
- Pg.173-184
- Pg. 216 (Radiographic Intensifying Screens) – 221 (stop before Screen-Film Combinations)
- Pg. 251 (Image Detail)- 252 (stop before Radiographic Technique Charts)