# Statistical Approach to Medical Image Errors Analysis

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# Overview of presentation

- System approach, error analysis noise
- The factors that affect the image quality
- Use of error analysis technique
- Statistical example
- Summary

# System Approach

- A system is “a group of interrelated inter acting components”; the higher the # of components&steps the more complex sys.
- There is a variation in each components or (step in process) that has normal distribution
- Quality production or service strives to reduce or eliminate the variation.

# Noise analysis is related to Quality

- Noise is unwanted information that crowds or could even mask the useful information.
- Reducing or eliminating noise improves the quality.
- In technical spheres Quality is defines as “conformance to specifications”

# Factors affecting Image Quality

- Tow Categories  1-Photographic  2-Geometrics
- Contrast*
- Blur
- Noise
- Artifacts
- Spatial and Geometry

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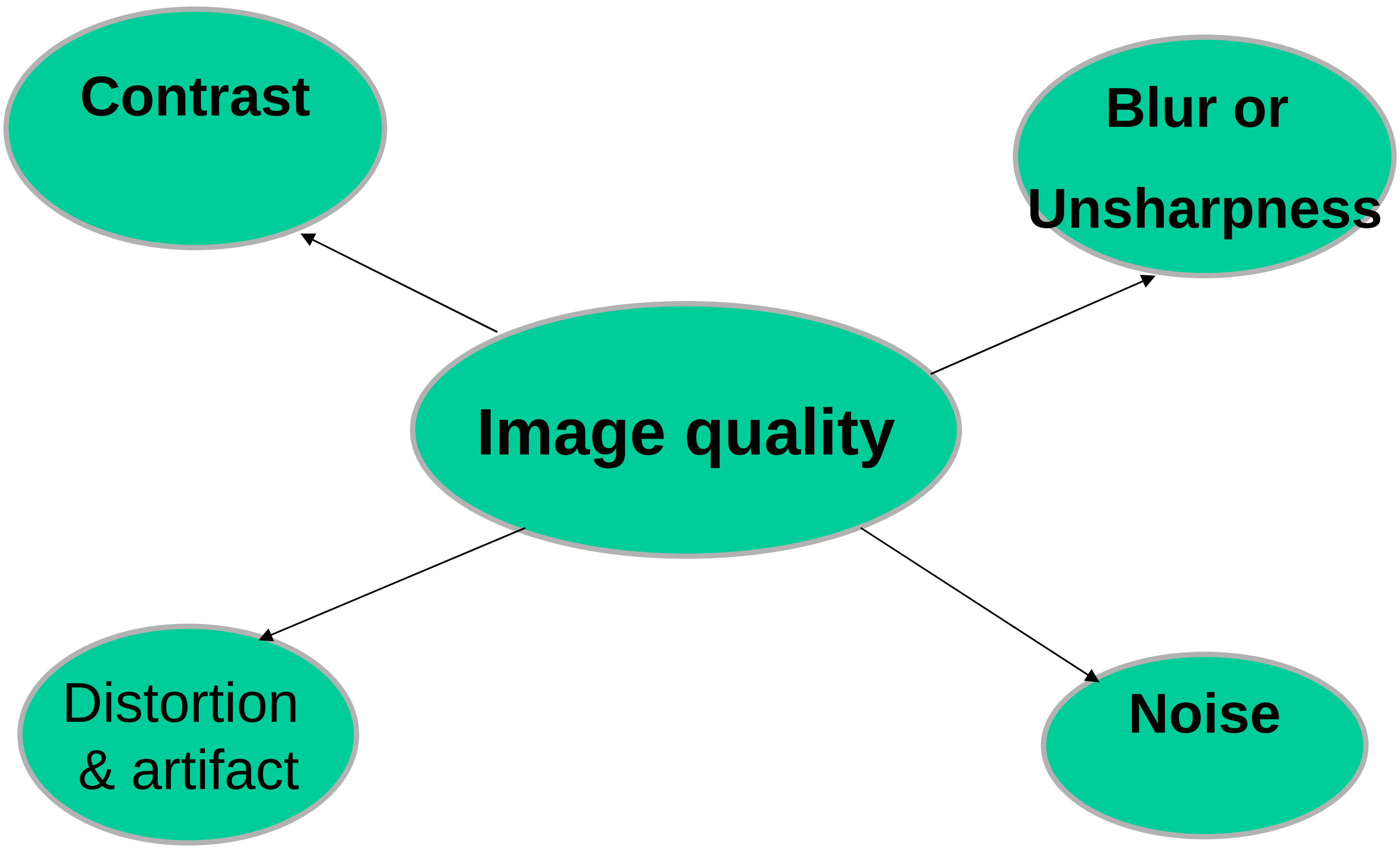
*Ref: Physical Principles of Medical Imaging P. Sprawls

# Factors affecting image quality



# Image Contrast

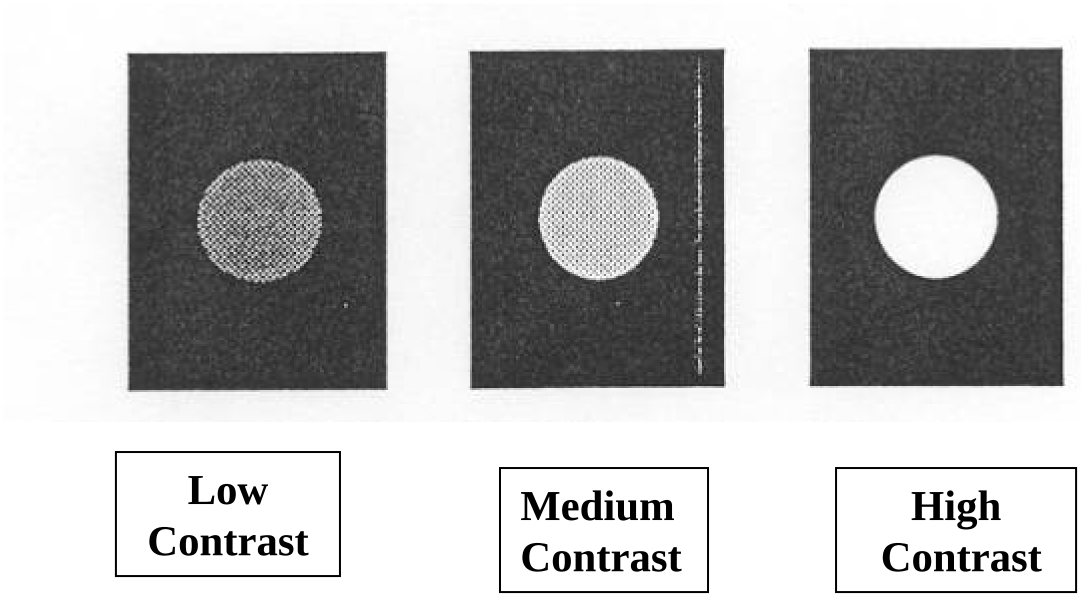



Image contrast refers to the fractional difference in optical density of brightness between two regions of an image

# Some factors influencing contrast

- **Radiographic or subject contrast**
  - Tissue thickness
  - Tissue density
  - Tissue electron density
  - Effective atomic number Z
  - X Ray energy in kV
  - X Ray spectrum (Al filter)
  - Scatter rejection
    - **Grid**
    - **Collimator**

- **Image contrast**
  - The radiographic contrast plus :
  - Film characteristics
  - Screen characteristics
  - Windowing level of CT and DSA

# Factors Related to Physics of x-ray

- Peak voltage value has an influence on the beam hardness (beam quality) (kVp)
- It has to be related to medical question
- What is the anatomical structure to investigate**?**
  - **What is the contrast level needed?**
  - For a thorax examination : 130 - 150 kV is suitable to visualize the lung structure
  - While only 65 kV is necessary to see bone structure

# Physical factors continued

- The higher the energy, the greater the penetrating power of X Rays
- At very high energy levels, the difference between bone and soft tissue decreases and both become equally transparent
- Image contrast can be enhanced by choosing a lower kVp so that photoelectric interactions are increased
- Higher kVp is required when the contrast is high (chest)

# Other Physical Factors

- The mAs controls the quantity of X Rays
- X Ray intensity is directly proportional to the mAs
- Over or under-exposure can be controlled by adjusting the mAs
- If the film is too “white”, increasing the mAs will bring up the intensity and optical density
- (Rule of thumb is 15% increase in mAs doubles the intensity)

# Effect of  kVp-mAs on Image

**60 kV - 50 mAs**


**70 kV - 50 mAs**

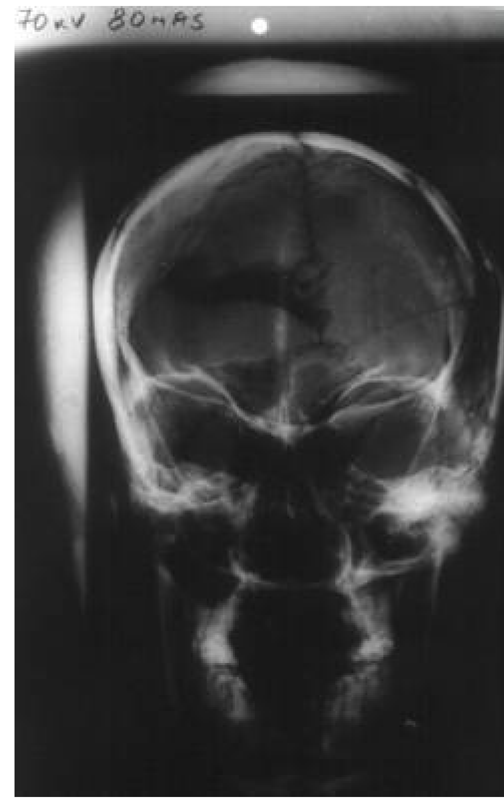

**80 kV - 50 mAs**

# More Examples, effects of kVp-mAs

**70 kV - 25 mAs**


**70 kV - 50 mAs**


**70 kV - 80 mAs**



# Other Factors Affecting Images

- The film as receptor has a major role to play in altering the image contrast
- There are high contrast and high sensitivity films
- The characteristic curve of the film describes the intrinsic properties of the receptor (base + fog, sensitivity, mean gradient, maximum optical density)
- Film processing strongly has a pronounced effect on fog and contrast

# Contrast

- Nature has provided limited contrast in the body
- Contrast creating agents are employed to achieve contrast when natural contrast is lacking or not enough (iodine, barium)
- The purpose is to get signals different from the surrounding tissues and make visible organs that are transparent to X Rays

# Image Lack of Sharpness

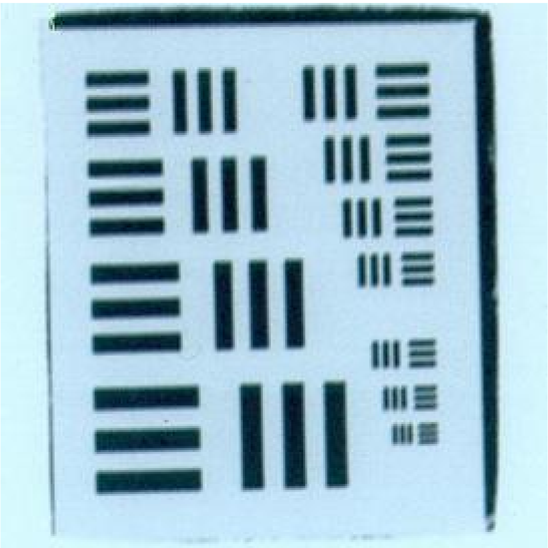
- The boundaries of an organ or lesion may be very sharp but the image shows a lack of sharpness
- Different factors may be responsible for such a degree of “fuzziness” or blurring
- The radiologist viewing the image might express an opinion that the image lacks “detail” or “resolution” (subjective reaction of the viewer to the degree of sharpness present in the image)

# Resolution

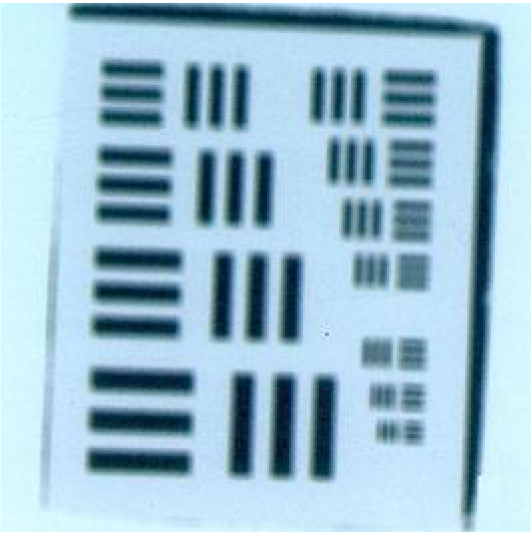
- Smallest distance that two objects can be separated and still appear distinct
- Example of limits (difrnt limit in difrnt medium)
    - Film screen: 0.01 mm
    - CT: .5 mm
- Other definition: “Point-spread” function
    - Characteristic of a “point” object
    - Point object expected to be point in image
    - Blurring due to imperfections of imaging system
    - Measurement:  full-width-at-half-maximum FWHM

# Geometric Blur

- As If the focal spot is infinitesimally small, the blur is minimized because of minimal geometric bluntness the focal spot increases, the blur in the image increases



**Small focal spot**



**Large focal spot**

# Geometric Blur

- Another cause of lack of geometric sharpness is the distance of the receptor from the object
- Moving the receptor away from the object results in an increased lack of sharpness
- N.B.: The smaller the focal size and closer the contact between the object and the film (or receptor), the better the image quality as a result of a reduction in the geometric sharpness

# Lack of sharpness in object

- Not all structures in the body have well-defined boundaries (superimposition essentially present in most situations)
- The organs do not have square or rectangular boundaries
- The fidelity with which details in the object are required to be imaged is an essential requirement of any imaging system
- The absence of sharpness, in the subject/object is reflected in the image

# Lack of sharpness due to motion

- Common and understandable blur in medical imaging
- Patient movement :
  - uncooperative child
  - organ contraction or relaxation
  - heart beating, breathing etc.
- Voluntary motion can be controlled by keeping examination time short and asking the patient to remain still during the examination

# Lack of sharpness due to motion continued

- Shorter exposure times are achieved by the use of fast intensifying screens
- Faster screens result in loss of details (receptor sharpness)
- Further, the use of shorter exposure time has to be compensated with increased mA to achieve a good image
- This often implies use of large focal spot (geometric sharpness)

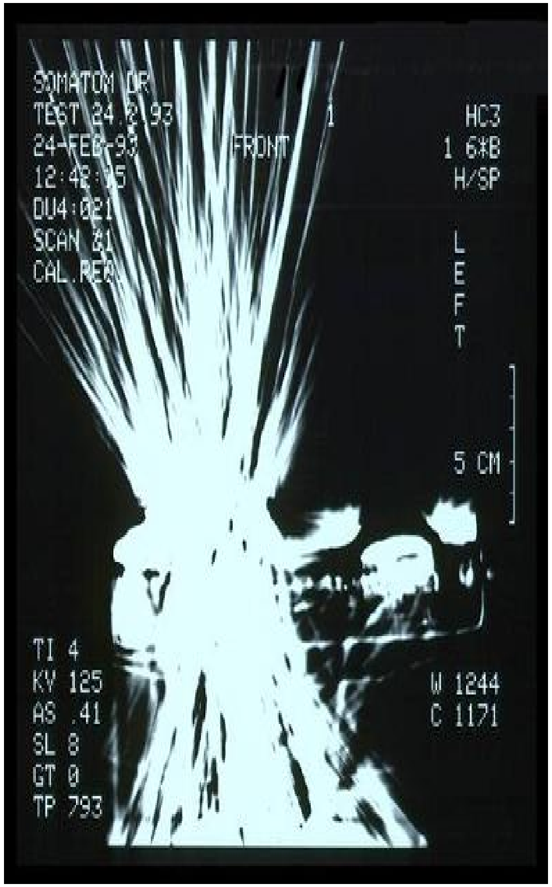
# Lack of receptor sharpness

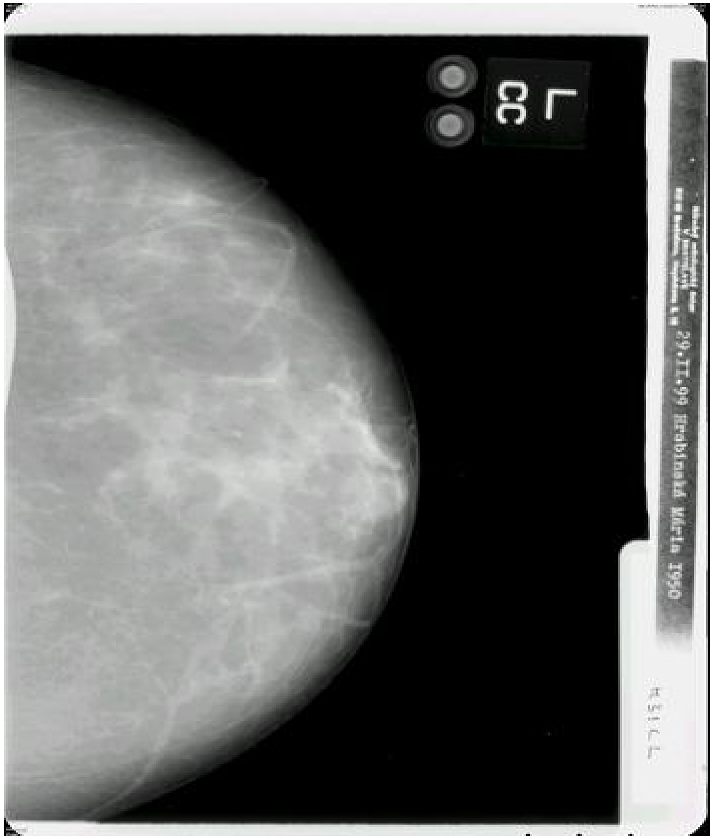
- The intensifying screen in radiography has a crystal size which is larger than that of the emulsion on the film
- An image obtained without the screen will be sharper than that obtained with the screen, **but** will require much more dose
- The thickness of the screen further results in degradation of sharpness
- On digital imaging, the image displayed at a higher matrix with a finer pixel size has better clarity

# Distortion and artifact

- Unequal magnification of various anatomical structures
- Inability to give an accurate impression of the real size, shape and relative positions
- Grid artifact (grid visualized on the film)
- Light spot simulating microcalcifications (dust on the screen)
- Bad film screen contact, bad patient positioning (breast)

# Distortion and artifacts



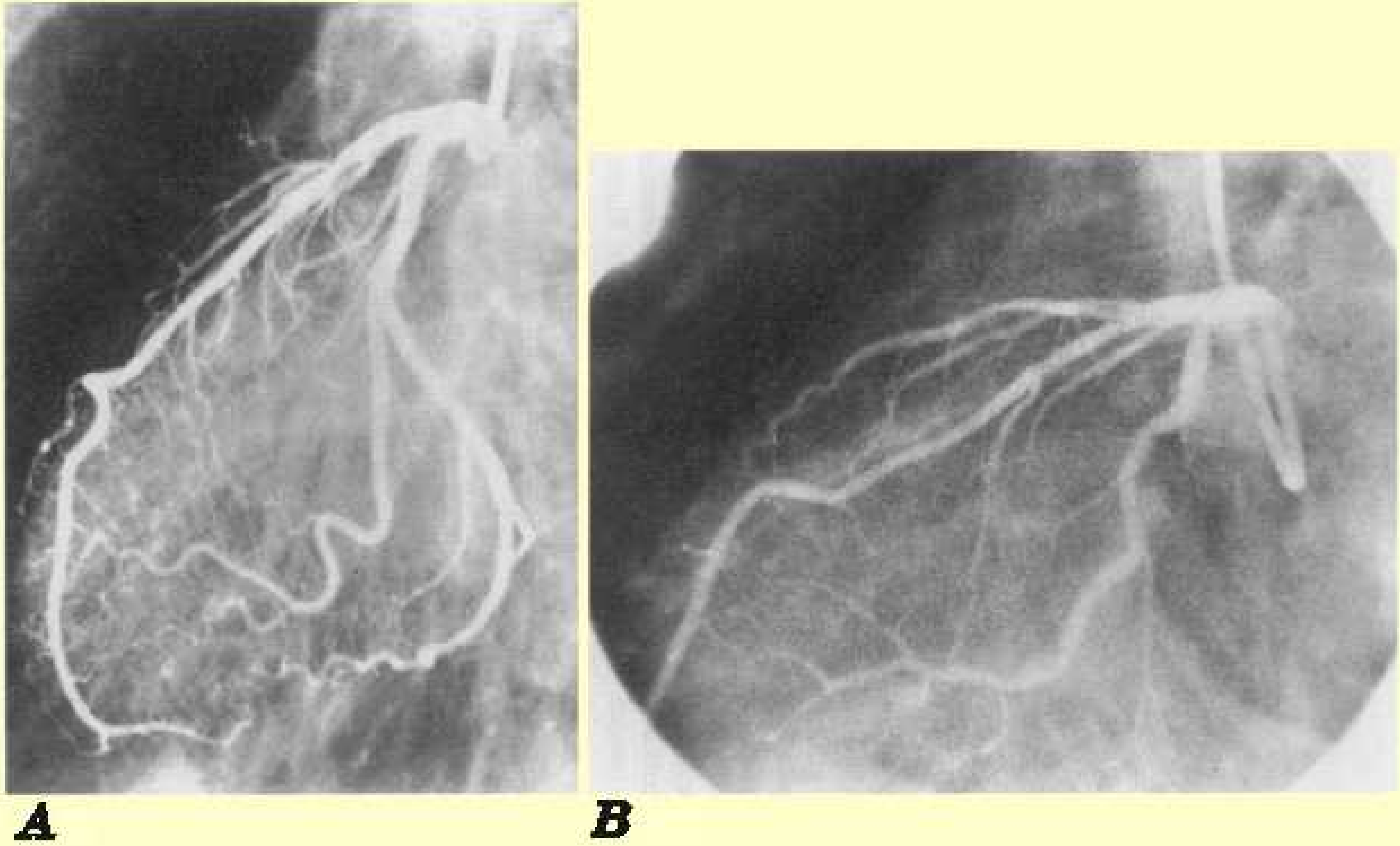



# Some Statistical Ana Case Results

- 1883 Images were analyzed
- Mean intrafraction and interfraction errors ( +/- SD) were 2.17 & 3.7$\pm$0.9 mm
- Lateral ( x) 2.3$\pm$0.9
- Cranio- caudal ( y) 3.1$\pm$0.9
- Anterior- posterior ( z) axes 3$\pm$0.7mm
- Random errors were 2.5, 2.4, & 1.8 mm on the x, y, and z

# Noise

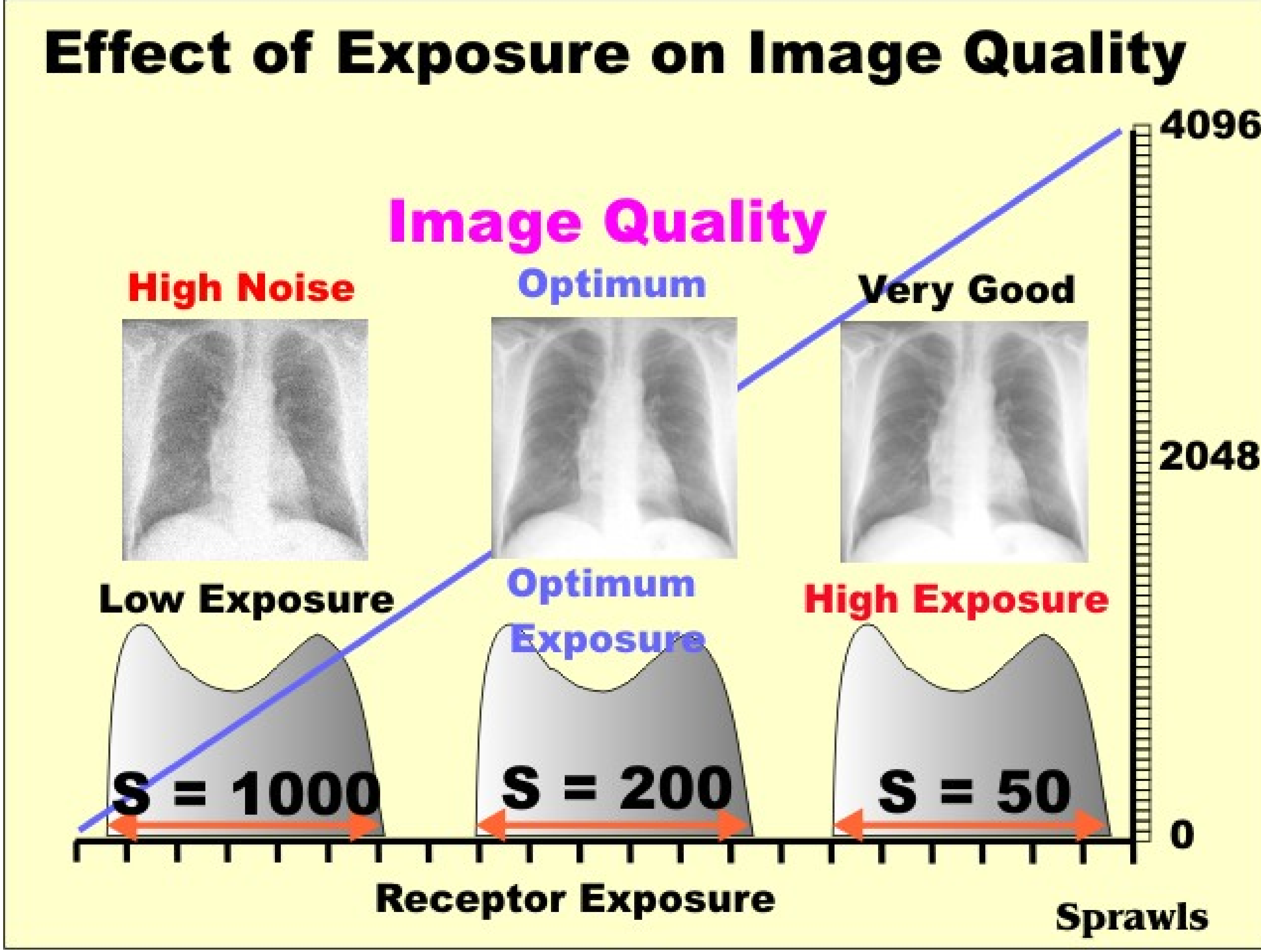
- Defined as uncertainty or imprecision of the recording of a signal
- Impressionist painting: precision of object increases with number of dots
- X Ray imaging: when recorded with small number of X-photons has high degree of uncertainty, more photons give less noise
- Other sources of noise:
  - Grains in radiographic film
  - Large grains in intensifying screens
  - Electronic noise of detector or amplifier




**The Image on the Right *(B)* Has More Noise Than the Image on the Left *(A)***

# Image Noise

- Information that is not useful is noise
- The snowing in a TV image, the speckles in an ultrasound image are examples of noise
- Noise interferes with visualization of image features useful for diagnosis
- Different components of noise are:
  - Radiation noise (“heel effect”)
  - Structure noise (Compton scattering)
  - Receptor noise (non-uniform response to a uniform X Ray beam)
  - Quantum mottle (low photon flux)




Images Produced with Different Exposures Throughout the Wide Dynamic Range of a Digital Radiographic Receptor.

# Use of Error analysis Technique

- Relating a set of independent $X_i$ variables to a Dependent variable Y

$$DY/Y = S_i^{m} S_i DX_i / X_i + S_{m+1}^{n} S_i DX_i / X_i + \cdots$$

- Where each summation represents errors associated with one group of components
- They Include "Systematic & Random" sources of errors.

# Noise in film

- Noise is characterized by the standard deviation ($\sigma$) of the OD measurements in any uniform region of the film

# Statistical parameters as tool of Error analysis

Mean $x = S^{n}_{i=1}\ x_{i}\ /n$

$Erms = [\ S^{n}_{i=1}\ s_{i}^{2}\ ]1/2$

Gradients of mean

Gradient of rms

# Summary

- Many Instrumental, procedural and performance factors influence the image quality at various levels
- Statistical techniques are able to quantify some of the factors affecting image analysis that in turn can help to improve image quality.

# Some of References


- Many sites on internet, plus
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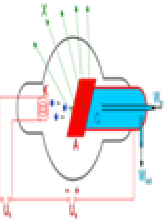

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