Data Acquisition Process-6

Image Production – Formation
Attenuation
Selectable Scan factors

Lambert-Beer Law for Beam Attenuation

- Is an exponential relationship which describes what happens to photons as they travel through tissue

- We are solving for the linear attenuation

Lambert-Beer Law: Equation

$$I = I_o e^{-\mu x}$$

- I is the transmitted intensity
- I_o is the original intensity
- x is the thickness of the object
- e is Eular's constant (2.718)
- μ is the linear attenuation

CT Numbers

- Each pixel in a reconstructed image is assigned a CT number or Hounsfield unit (HU)
- CT numbers are related to the linear attenuation coefficient of the tissue that comprises that slice.
- Original CT numbers were based on a contrast factor of 500 and referred to as EMI numbers with a contrast scale of 0.2%

CT Numbers (cont'd)

- Now based on a contrast factor of 1000 and called Hounsfield Units with a contrast scale of 0.1% (each number is .1% different than the next)

- CT numbers are established on a relative basis with the attenuation of water used as the reference

- Water=0 Bone= 1000 Air= -1000

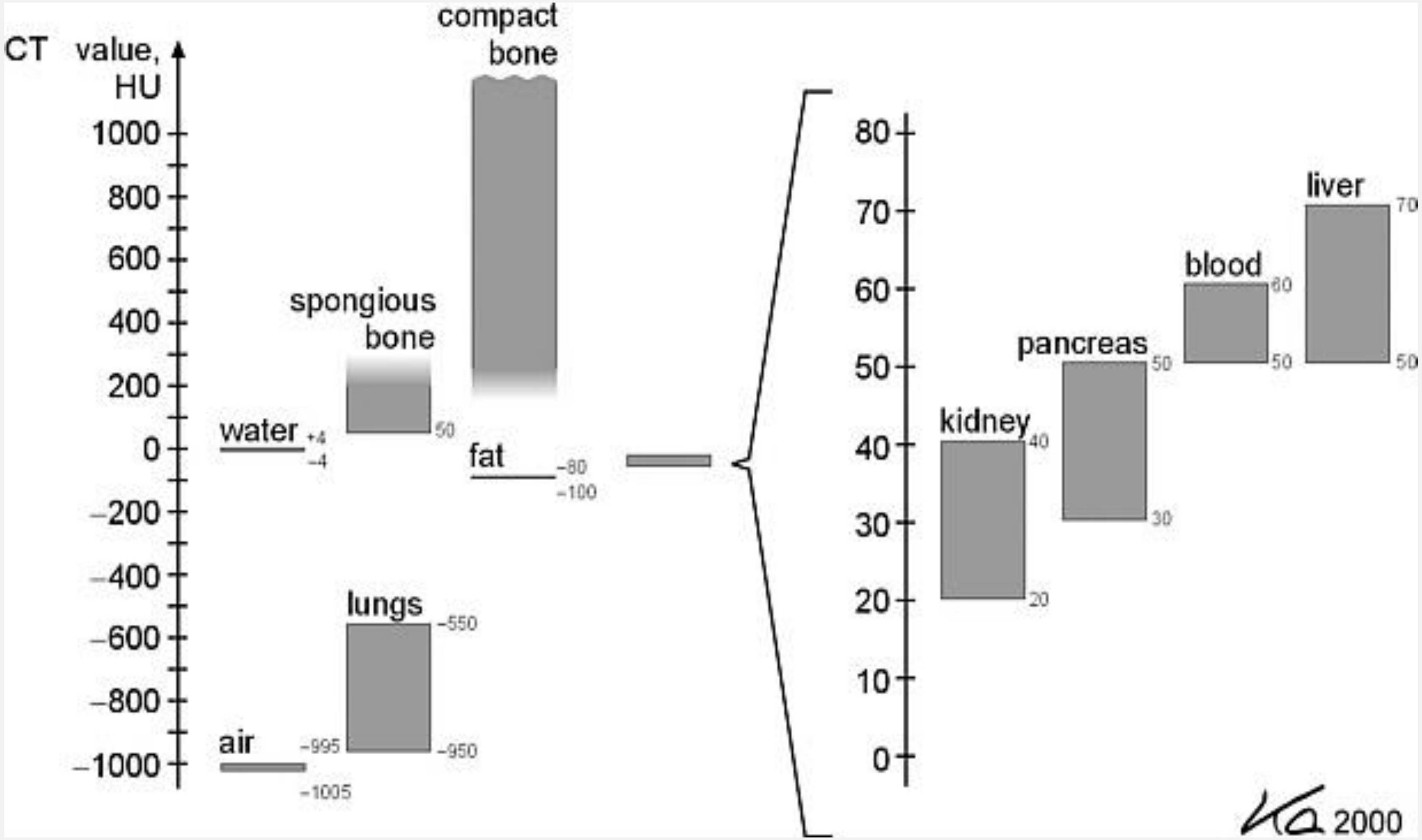
- Computer calculates CT numbers which are converted into a gray-scale image

CT Numbers of Some Tissues

- **Water = 0**
- **Air = -1000**
- **Bone = +1000**
- **Note what is more or less dense than water**

Tissue	CT Number (HU)
Bone	+1000
Liver	40 - 60
Whiter mater	−20 to −30
Grey mater	−37 to −45
Blood	40
Muscle	10 - 40
Kidney	30
CSF	15
Water	0
Fat	−50 to −100
Air	−1000

Comparison of Relative CT Numbers



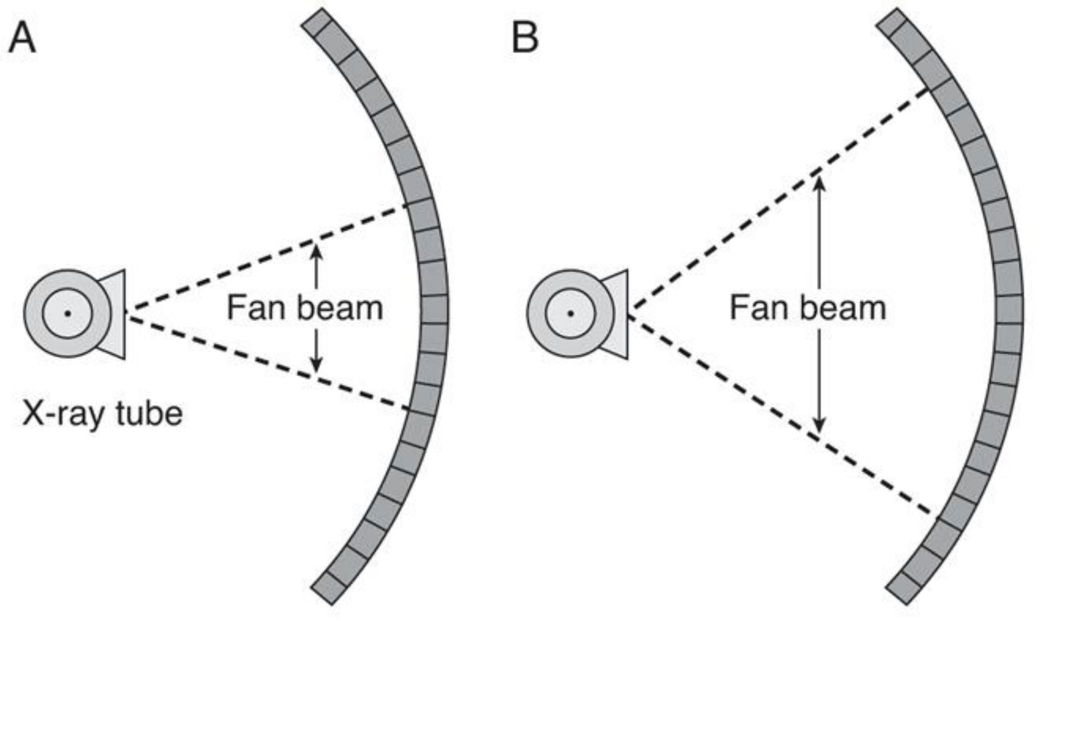
$$\frac{\mu_{Tissue} - \mu_{H_2O}}{\mu_{H_2O}} \times 1000 = \text{IMAGE PIXEL CT NUMBER}$$

- **CT Numbers are computed by calculating the difference between the attenuation of tissue and that of water**
- **These tissue attenuation coefficients are obtained from a table for a given kVp.**
- **Example** $\frac{0.38 - 0.19}{0.19} \times 1000 = \frac{0.19}{0.19} \times 1000 =$

1 x 1000 = 1000   So this tissue has a CT number of 1000

Scan Field of View

- Selecting SFOV determines the area within the gantry where the raw data are acquired
- SFOV is in the isocenter of the gantry
- SFOV selection determines the number of detector cells collecting data



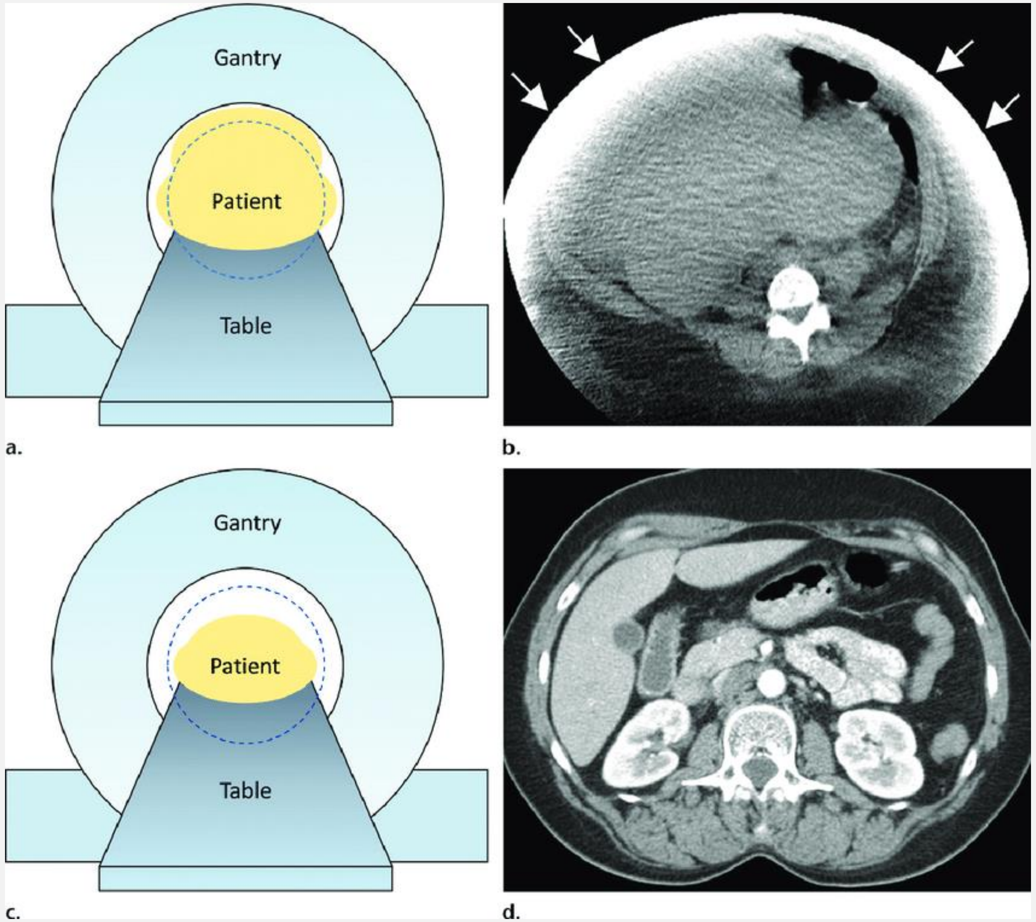
SFOV Choices

- Size of patient
  - Small (25 cm)
  - Medium (35 cm)
  - Large (42-50 cm)

- Types of image processing
  - 25 cm for Head
  - 25 cm for Body
  - Processed Differently due to anatomy

Scan Field of View (cont'd)

- Anything outside the SFOV is not imaged
- To produce the highest quality image, select the SFOV that comes closest to just encompassing the patient
- Parts of the patient located outside the SFOV may cause out-of-field artifacts on the image



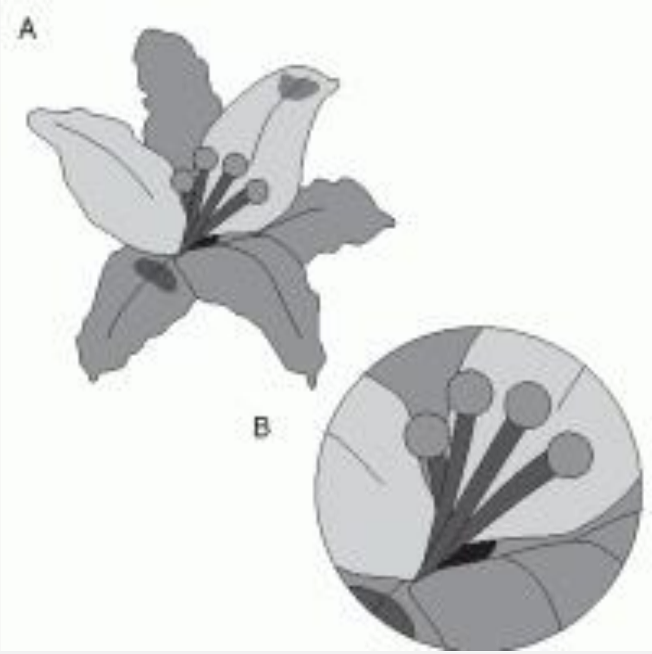
Display Field of View

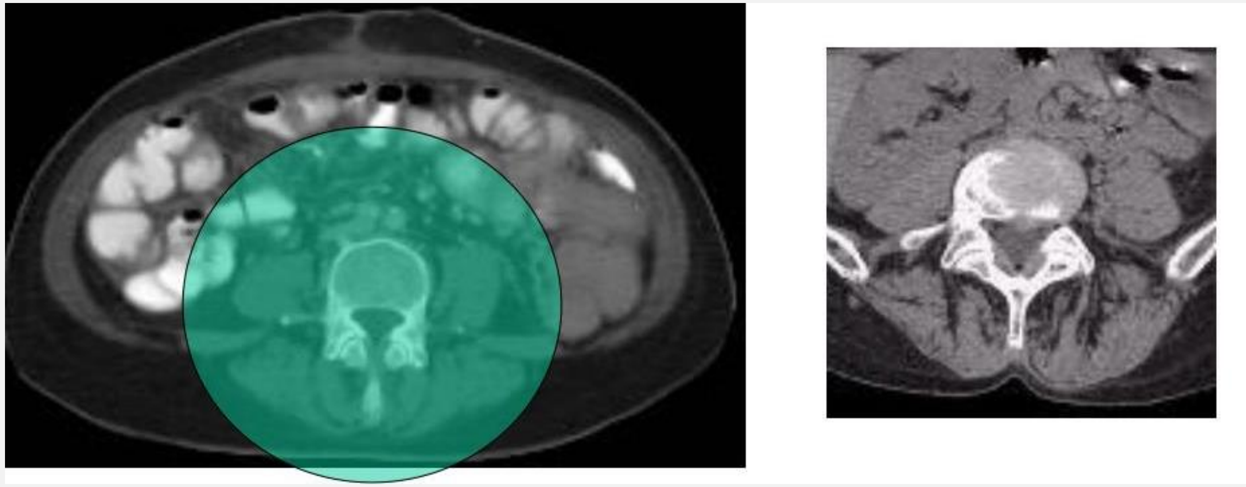
- DFOV selection determines how much of the collected raw data are used to create an image

- DFOV is also called zoom or target

- <u>Changing the DFOV affects image quality by changing the pixel size</u>

- DFOV works in a manner similar to the zoom on a camera





Display Field of View

- **Because the data selected for the DFOV are a subset of all the scan data available, the DFOV cannot be larger than the SFOV**

- **Choosing the optimal DFOV improves the detectability of abnormalities**

    - **A DFOV that is too large makes anatomic structures unnecessarily small**

    - **A DFOV that is too small may exclude important patient anatomy**

Image Center

- Image coordinates allow the operator to specify the area within the SFOV that will be displayed on the image
- Some manufacturers use *x* and *y* preceding the number to designate the direction of the coordinates
- Some manufacturers precede the number by R (right), L (left), A (anterior), P (posterior), S (superior), and I (inferior)
  - Often referred to as RAS coordinates

Image Center Adjusted Using Traditional *X* - *Y* Coordinates

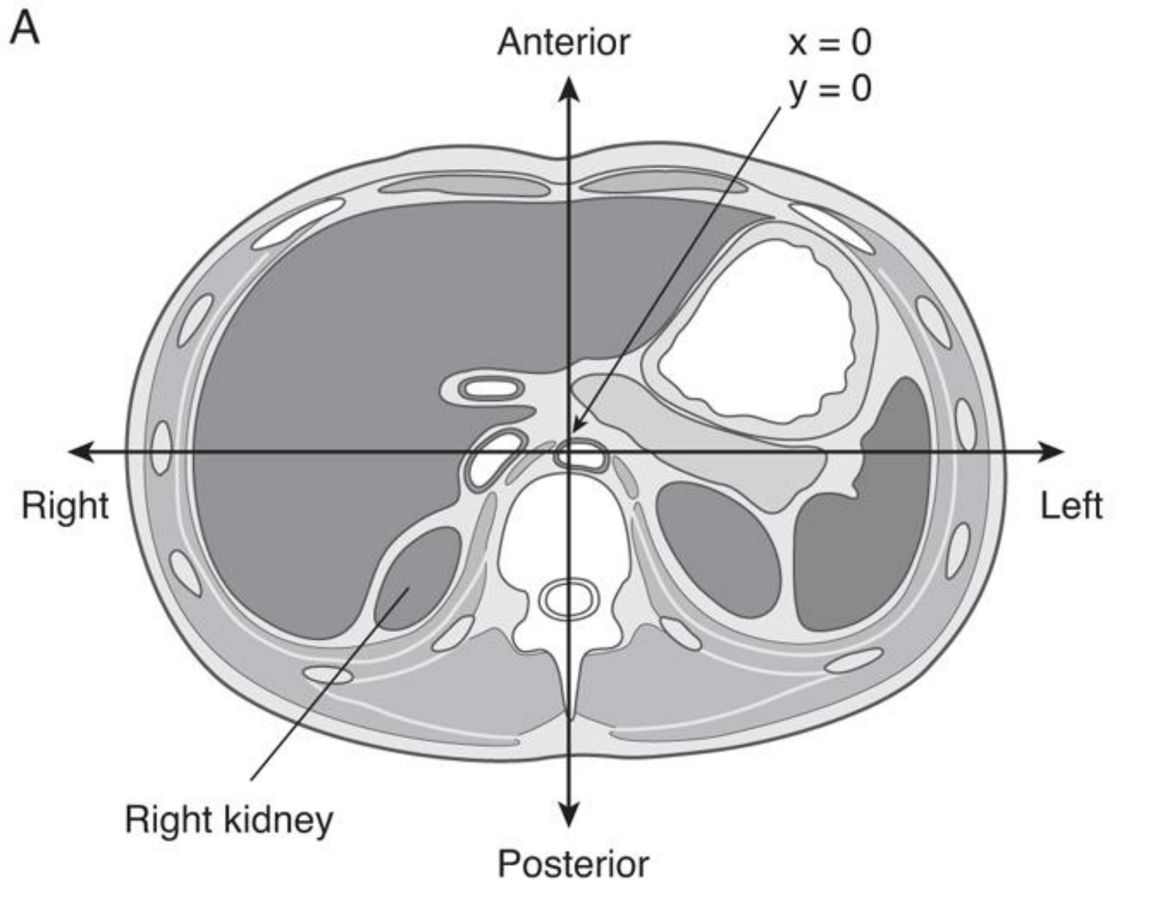
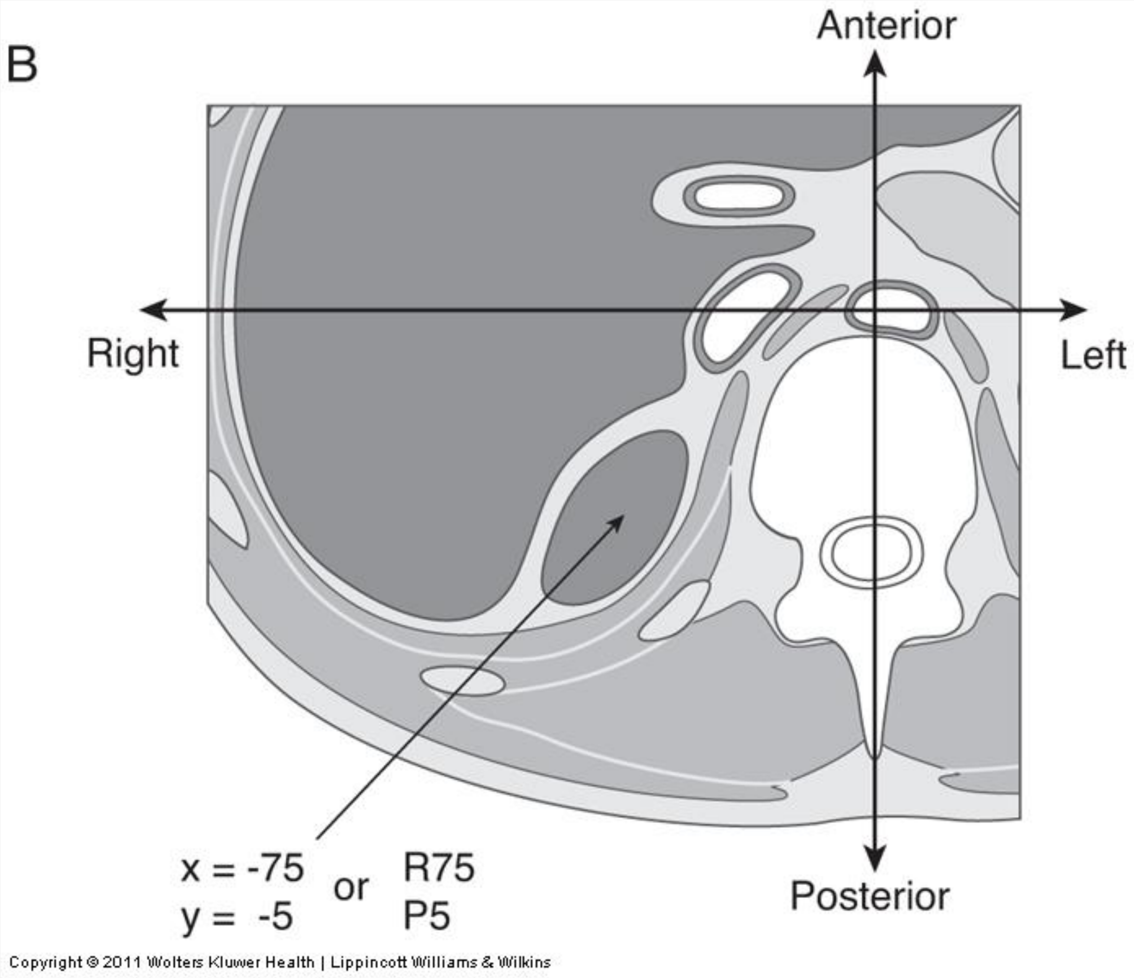


Image center adjusted using RAS coordinates

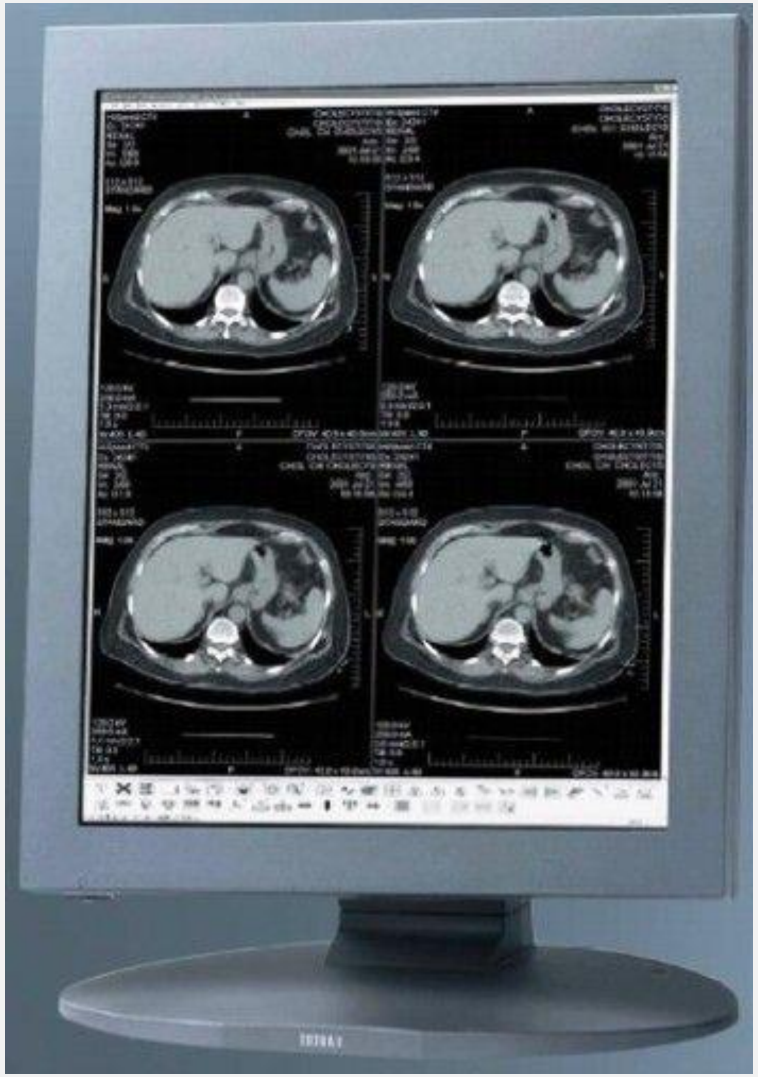
- Most often done by simply placing cursor on are to be centered
- As shown in this slide



Display Monitors

- CT images are usually displayed on a black-and-white monitor

- Displays may be:
  - Images
  - Scan Protocol Data (technique & radiation dose)
  - Patient Information



Cameras

- In some instances, CT images are transferred to film (almost never)
- The camera may be a multi-format camera, although most modern CT systems include a laser camera
- Multi-format cameras transfer the image displayed on the monitor to film
- Laser cameras bypass the video system entirely

Windowing

- Refers to a method by which the CT image gray scale can be manipulated using the CT numbers of the image.

- The brightness and contrast are controlled by the user

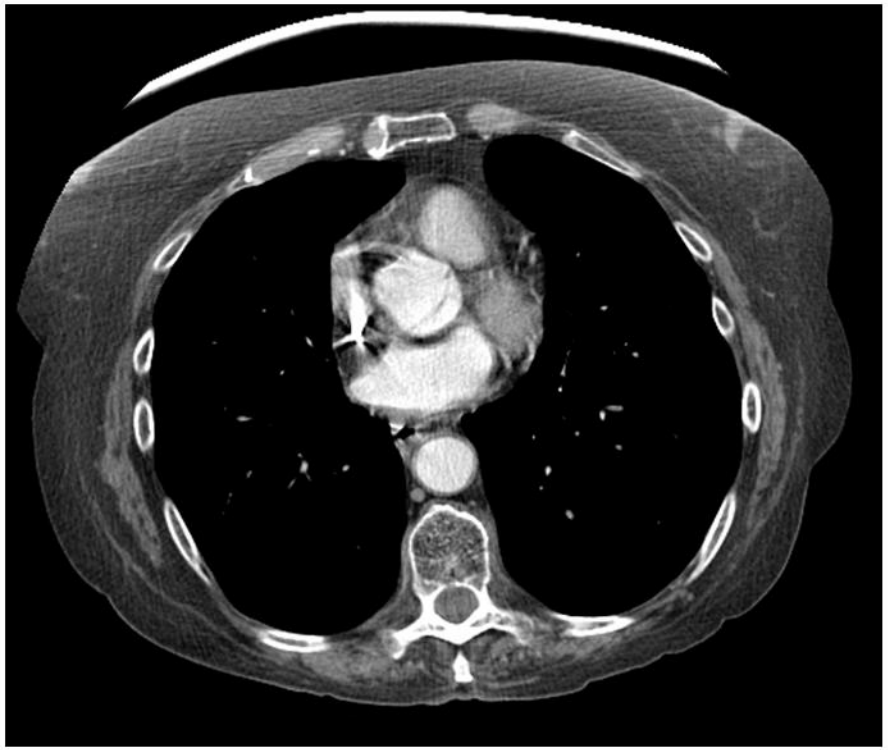
- Easily changed with two control mechanisms:
  - window width
  - window level

Window Settings

- Many studies require each image to be viewed at two or more window settings
- "Ideal" window settings are somewhat subjective
- Imaging departments typically have an established setting for each type of examination
- Because many factors have an effect on image, technologists must adjust settings in individual situations

Window Settings

- Adjusting the window width and window level will change the way an image is viewed on the monitor



Gray Scale

- The gray scale is used to display CT images

- This system assigns a CT number or groups of CT numbers to each shade of gray

  - Higher HU values lighter shades of gray or white
  - Lower HU values darker shades of gray or black

Gray Scale

- **Images cannot always be displayed with a different shade of gray for each HU (CT Number) because:**
  - **There are more 2,000 Hounsfield values; most monitors can only display 256 shades of gray**
  - **The human eye can differentiate only a fraction of those shades**
  - **As a general rule, the human eye cannot appreciate contrast differences of less than 10%, whereas CT scanners can easily demonstrate differences of less than 1%**

Hounsfield Scale

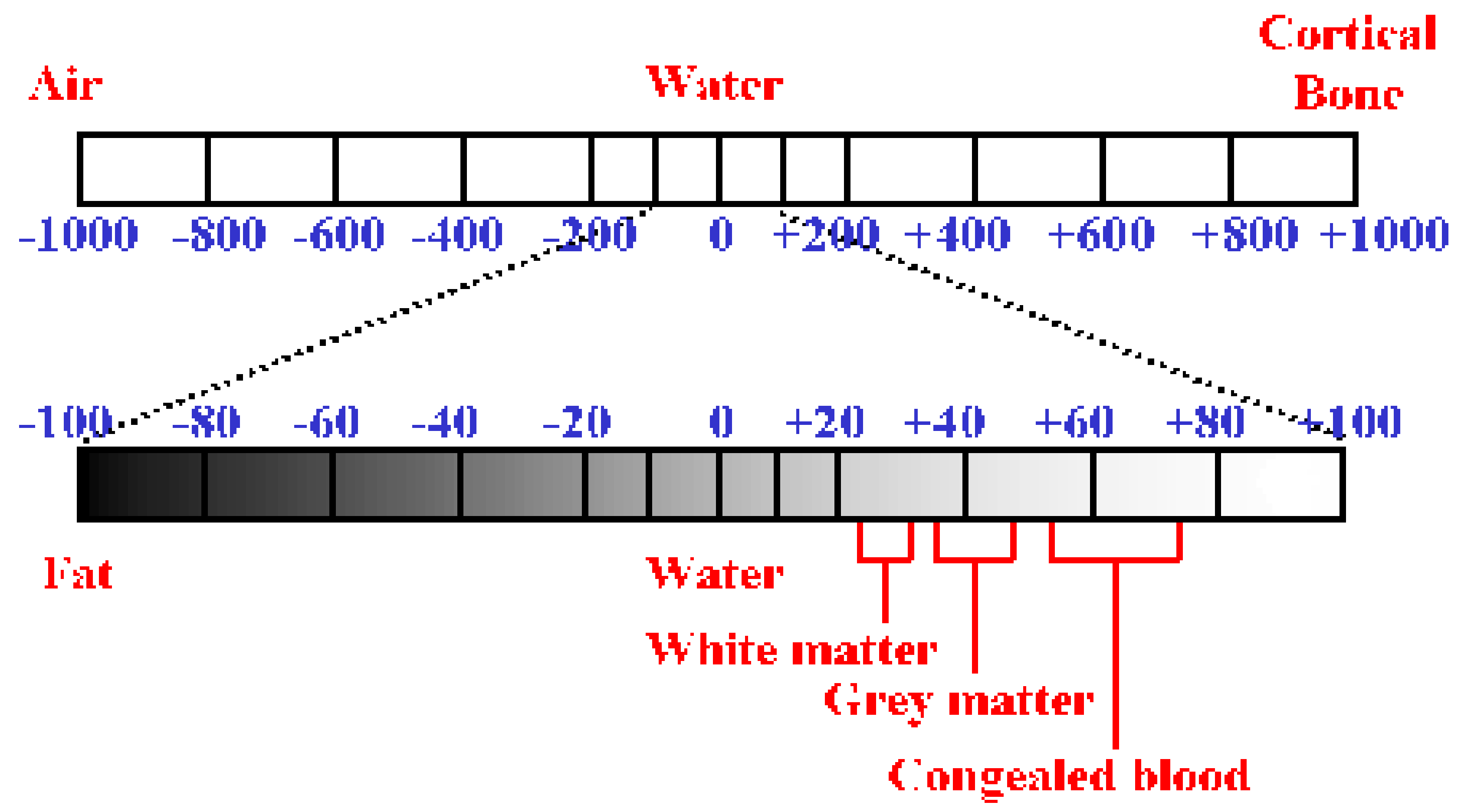


Image Manipulation

- Windowing is a type of image manipulation which modifies an image or group of images to enhance the visibility of useful information .

- **Does not produce any additional information. Just the same information presented differently.

Window Width

- Window Width Determines the number of CT Numbers represented as shades of gray on a specific image
- By increasing the window width more numbers are assigned to each shade of gray
- Wide window widths are best for displaying tissue types that vary greatly if the goal is to see all the various tissues on one image. (abdomen)
- Narrow window widths are best for displaying tissue types with similar tissue densities. (liver or brain)

More Window Width Info

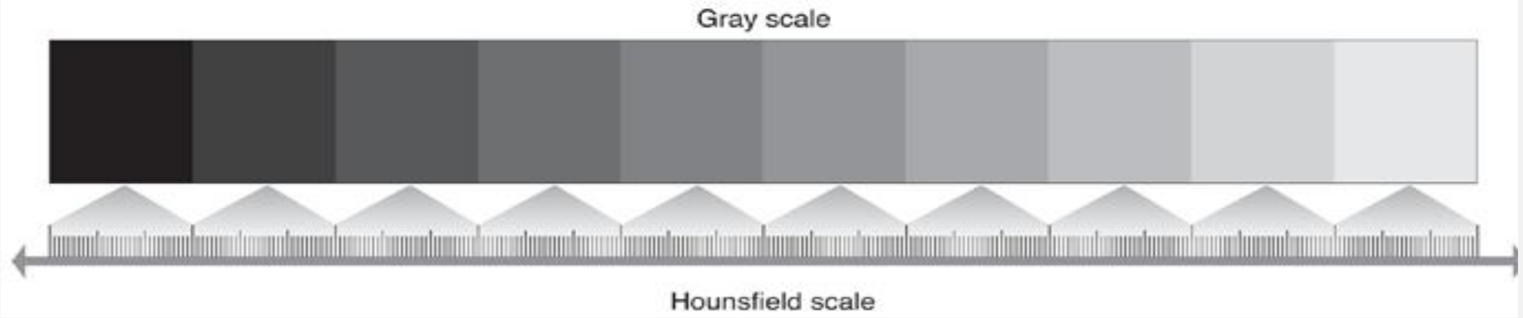
- Window Width sets the gray scale
- Top/Greatest value of the window will appear white as will all values higher
- Bottom/Lowest value of the window will appear black as will all values lower
- All of the values between the top and bottom will appear as varying shades of gray
- Narrow windows give more contrast (black and white)
- Wide windows give less contrast (many gray shades)

Window Width

- To illustrate, assume
  - we have just 10 shades of gray available
  - 300 is selected as the window width

- 300 density values will be represented on the image as shades of gray (of the more that 2000 possible densities)

- All others will be either black or white
- In this example 30 different HU will be grouped together



Varying Window Widths

- Narrow
  - Sharp contrast
- Medium
  - Usually optimal
- Wide
  - Low contrast

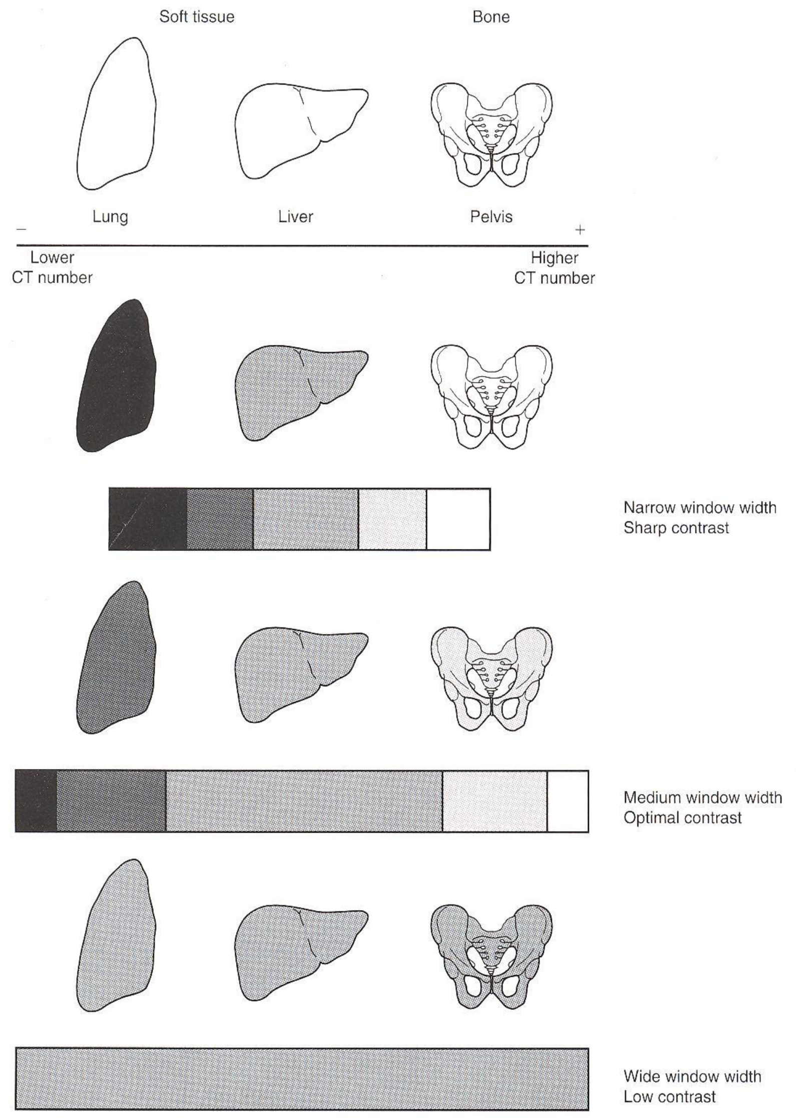
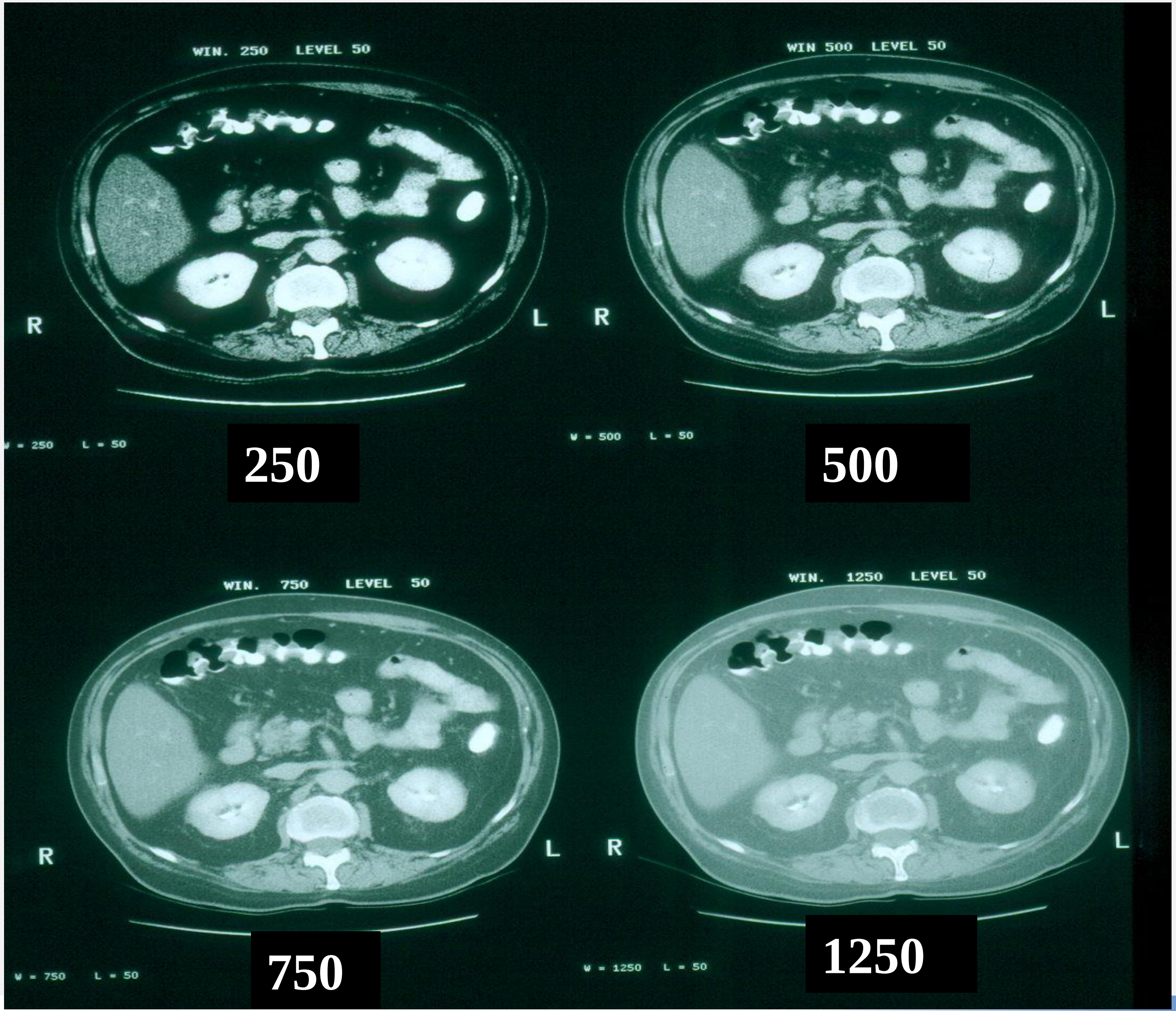
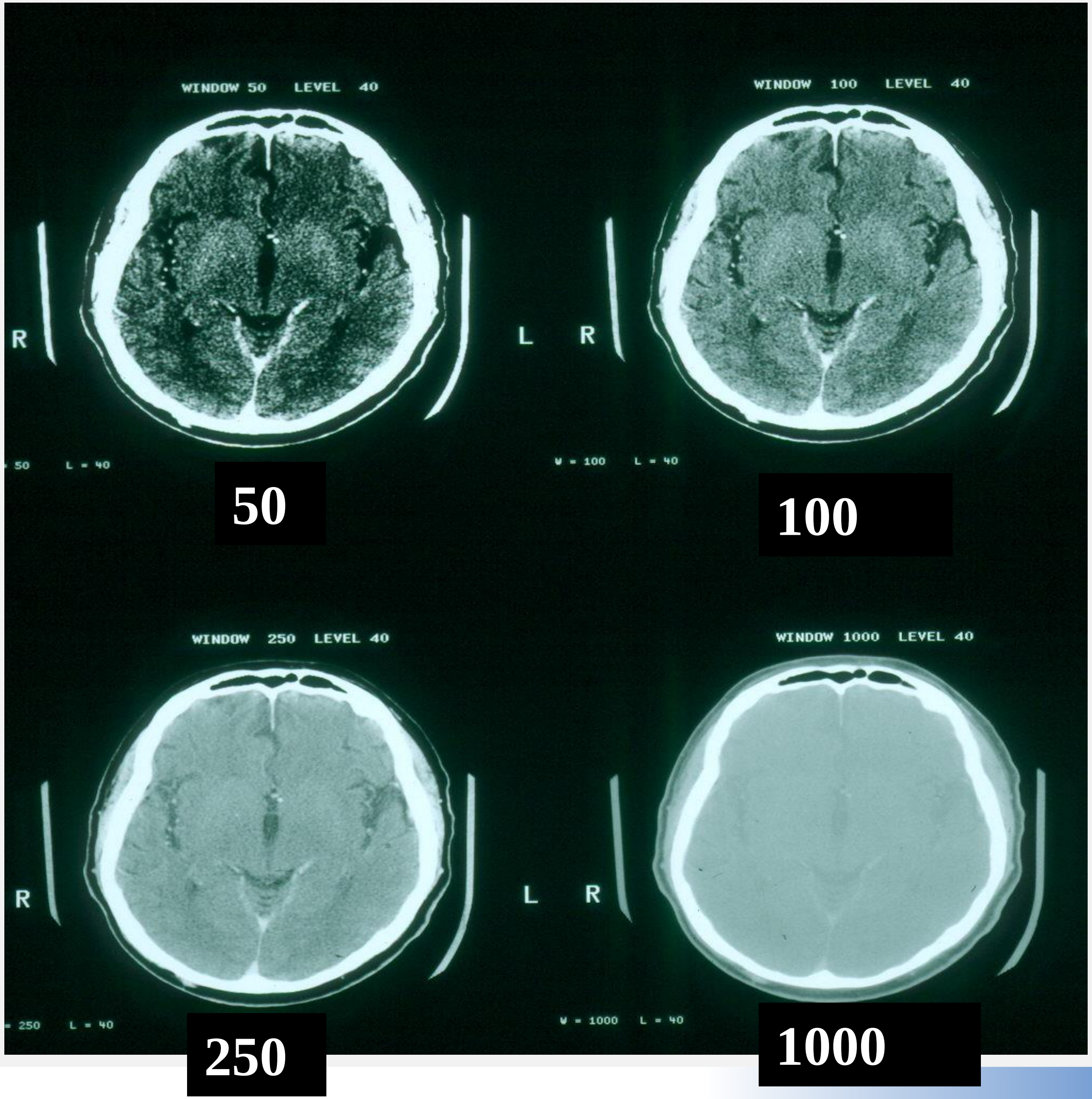


FIG. 8-7. The effect of window width on the appearance of different organs with widely varying CT numbers.

Window Width



Window Width



Window Level

- Window Level is the Midpoint or center CT value of the window width.
- Selects which Hounsfield units are displayed on the image.
- Used to change the overall density of an image
- Should be set at a point that is roughly the same value as the average attenuation number of the tissue of interest.
- Example 35-70 for abdomen and -700 for Lung
    - Higher the level -- darker the image
    - Lower the level – lighter the film

Window Levels

Lower Level

Lighter image

Higher Level

Darker image

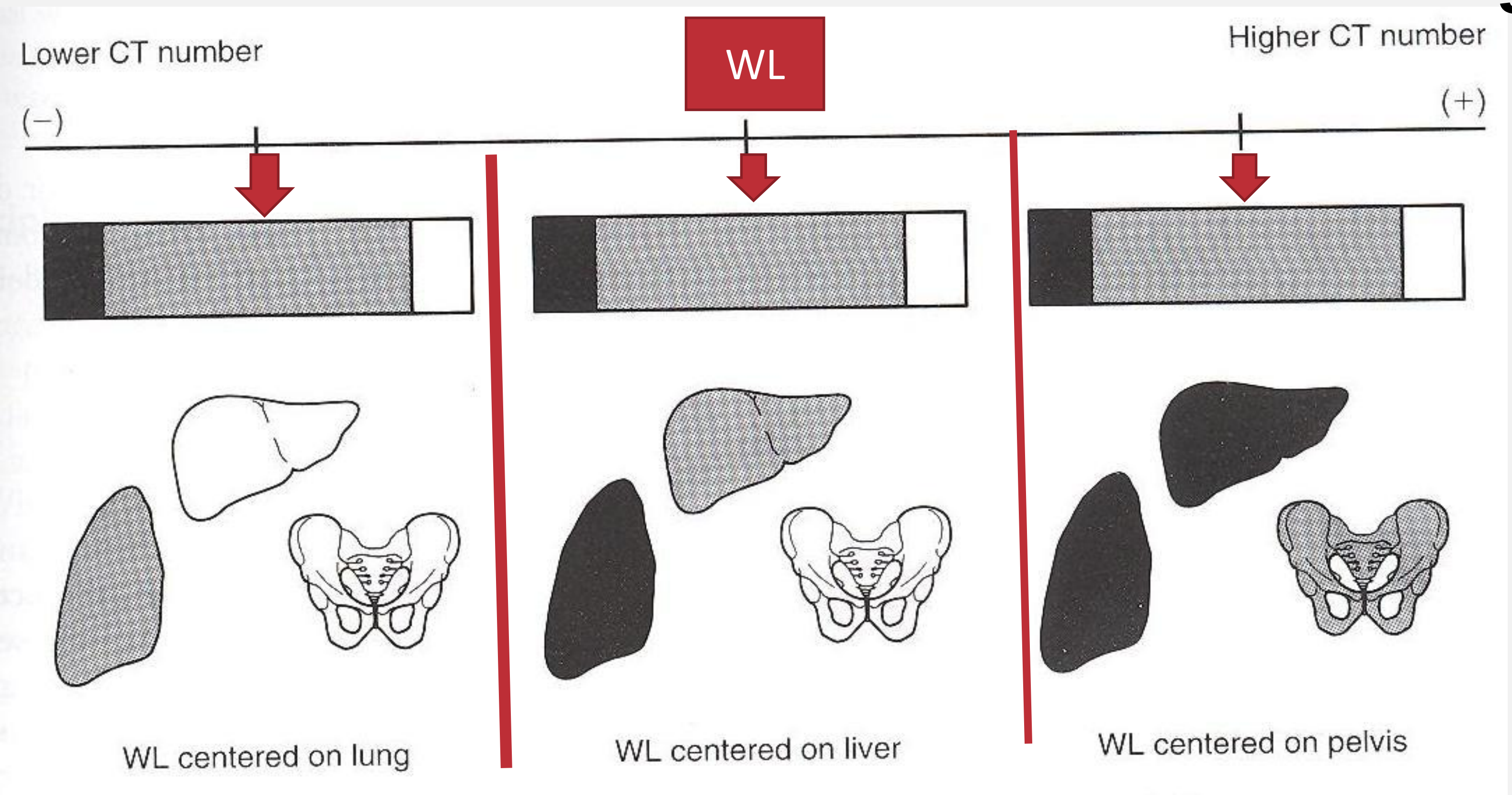
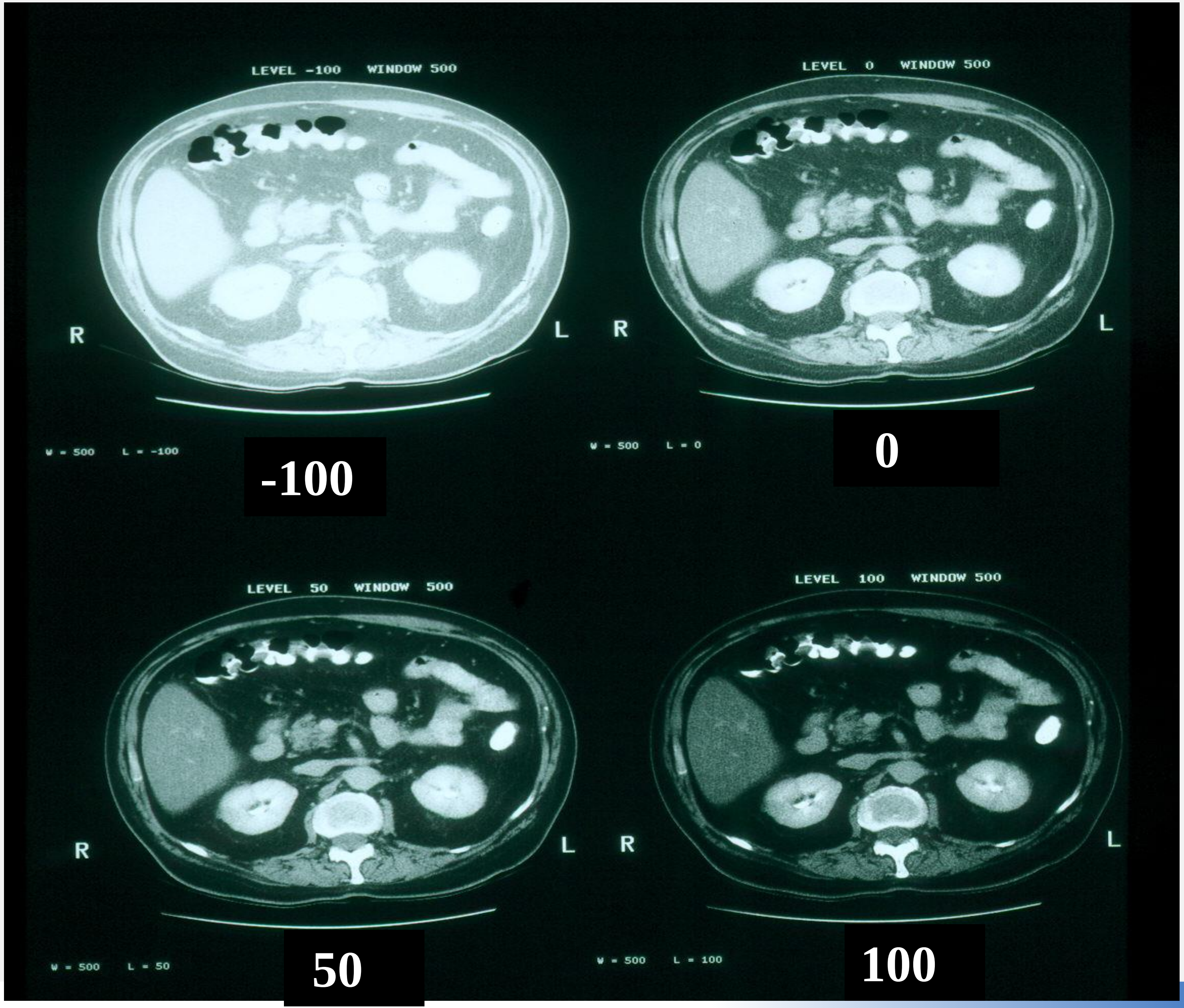
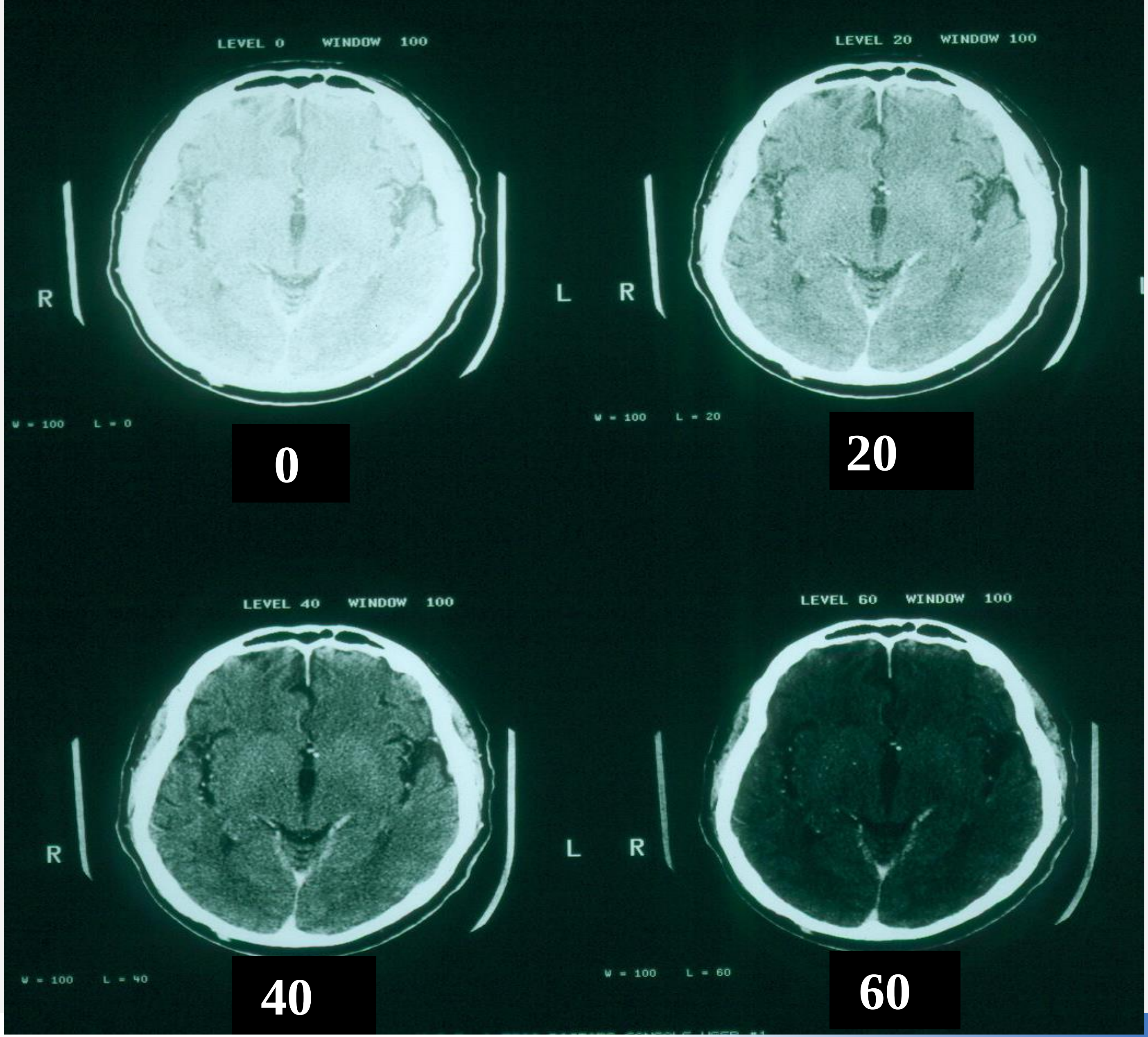


FIG. 8-9. The effect of window level (WL) on gray tone appearance of different organs.

Window Level



Window Level



Window Width/Window Level

- **If the window width is set at 300, which 300 Hounsfield values from the more than 2,000 will be displayed?**

- **Window width selects the *quantity* of HU displayed**

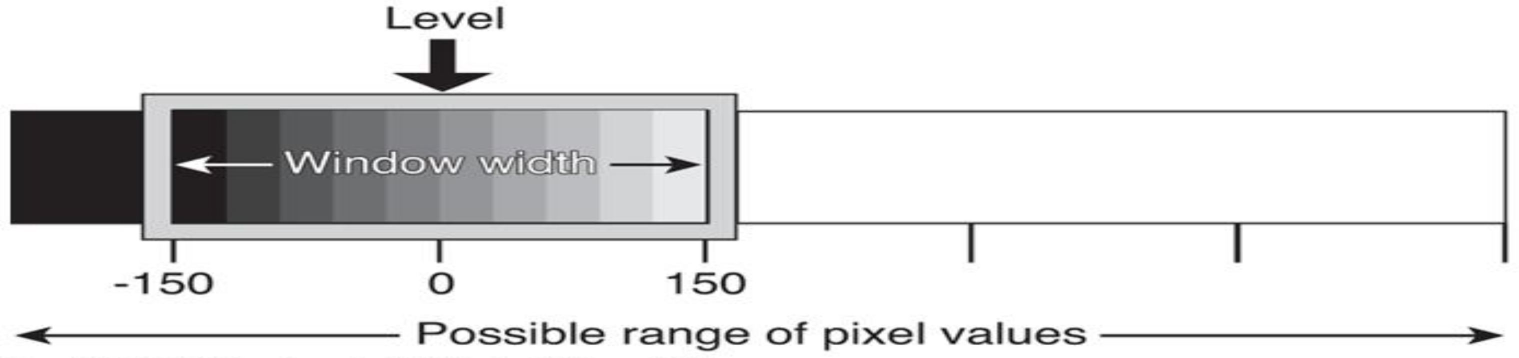
- **Window level selects the *range* of HU displayed**

Window Level

- **Continuing with the example of 300 as the window width, assume 0 is selected as the level**

- **The CT numbers that are represented as a shade of gray on this image will range**

from –150 to 150



Range of Numbers Displayed

- Range of Numbers
  - The HU values within a window width

- Values can be:
  - Positive
  - Negative
  - Both

- R= Range   L = Level   W = Window Width

- R = L + W/2 and L - W/2

R = L + W/2 and L - W/2

- Examples
  - L=175   W=200
  - R= 175   +   100   = 275

    175   -   100   =   75

- Range is 75 to 275
- All positive

R = L + W/2 and L-W/2

Example 2

- L=50 WW=100
- R= 50 + 50 = 100

  50 - 50 = 0

R= 0 to 100

Example 3

- L= -20 WW=100
- R = -20 + 50 = 30

  -20 - 50 = -70

R= -70 to 30

Review

- The selected window width is 400

- The selected window level is 50

- Which HUs are displayed on the image as shades of gray?
  a. –200 to 200
  b. –150 to 450
  c. –150 to 250
  d. 350 to 450

General Rule for Setting Window Level and Width

- The window level should be set at a point that is roughly the same value as the average CT number of the tissue of interest

- In general, wide window widths (500–2000) are best for imaging tissue types that vary greatly, when the goal is to see all of the various tissues on one image, such as lung

Image Display Options

- Pixel value
- ROI
- Standard Deviation
- Distance
- Measurements
- Image annotation

- Reference Image
- Image magnification
- Histogram
- Multiplanar Reformatting or Reconstruction (MPR)
  (Discussed in Chapter 8)

HU Measurement and Standard Deviation

- **HU measurements may be affected by volume averaging or image noise**

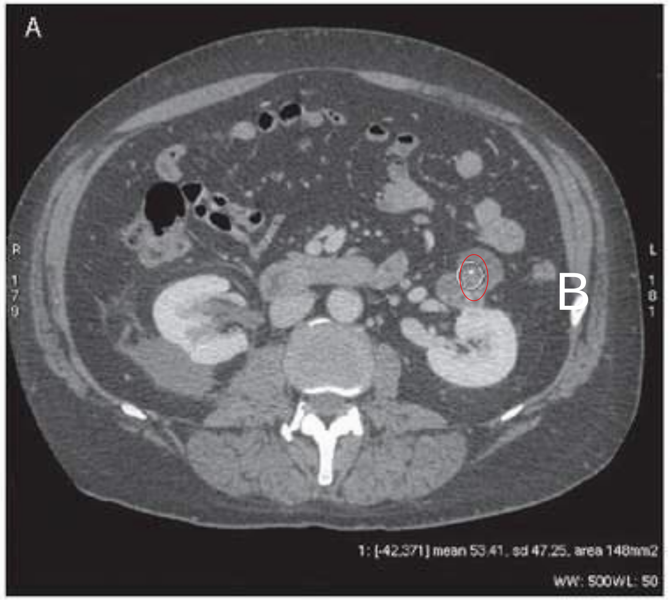
- **A cursor displays a measurement of the HU of the pixels that the cursor covers**

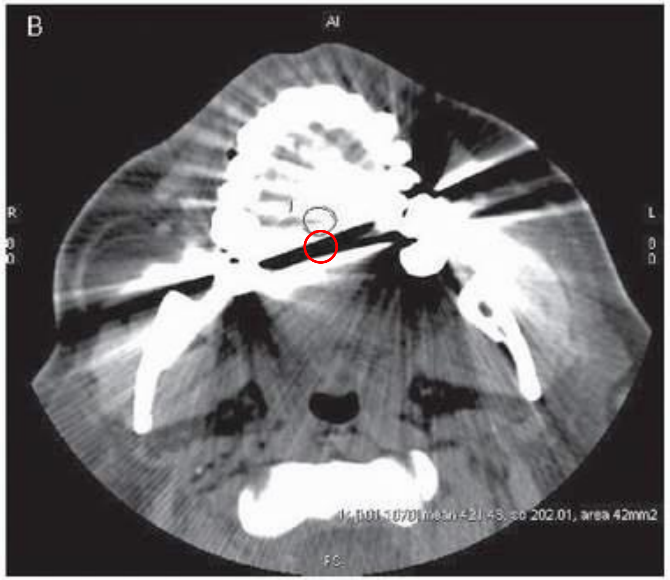
- **Conversely, an ROI provides an averaged measurement of all of the pixels within the ROI**
  - **When an ROI is used, the standard deviation is also displayed**

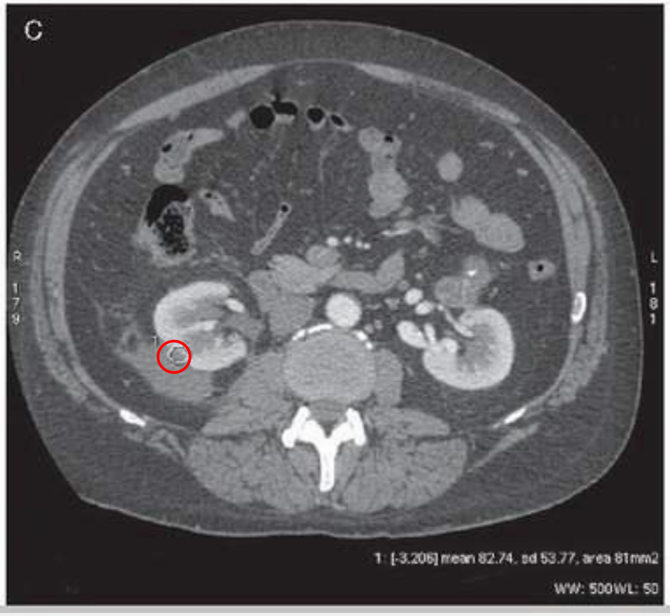
Region of Interest (ROI)

- Defined by the CT operator
- Circular, square, elliptical, rectangular or custom drawn
- Obtains averaged HU measurement and acquires the standard deviation
- The HU average is a reading of the average of all the pixels in the ROI
- The standard deviation indicates the amount of HU variance within the ROI

Factors that Produce High Standard Deviations







A - Mix Attenuation Tissue of calcium in an organ

B – ROI with Streak artifact

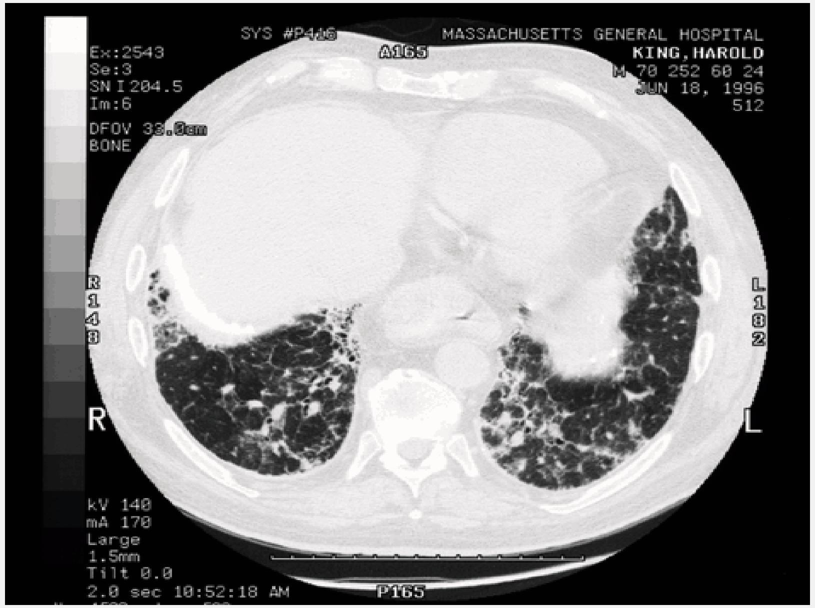
C – ROI with margins outside of object intended

DISTANCE MEASUREMENTS

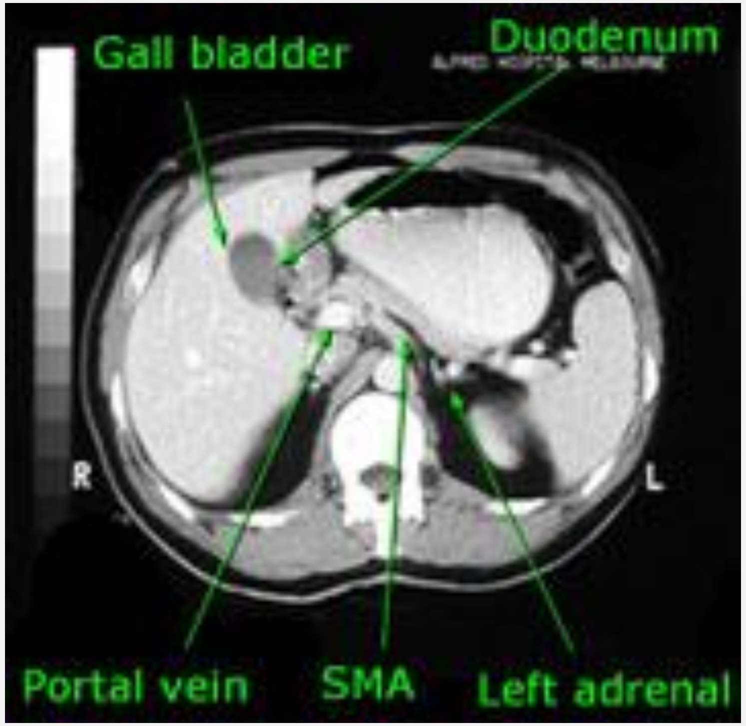
- Calculates distance between two points in cm or mm
- Calculates the angulations of the line from vertical and horizontal
- Essential for biopsy needle placement
- Helps determine the size of an abnormality

IMAGE ANNOTATION

- Can include:
  - Table location
  - Measurement scale
  - Gray scale
  - R/L indicators
  - Facility and patient name, ID number, Date
  - Thickness, Slice number
  - Scan parameter selections
  - Technical factors



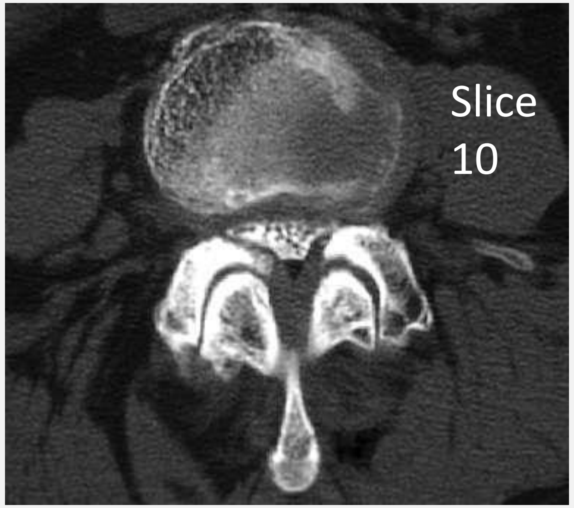
- **Specific annotations with symbols and words**



REFERENCE IMAGE

- Displays the slice lines in corresponding locations on the scout image

- Aides in localizing slices according to anatomical landmarks



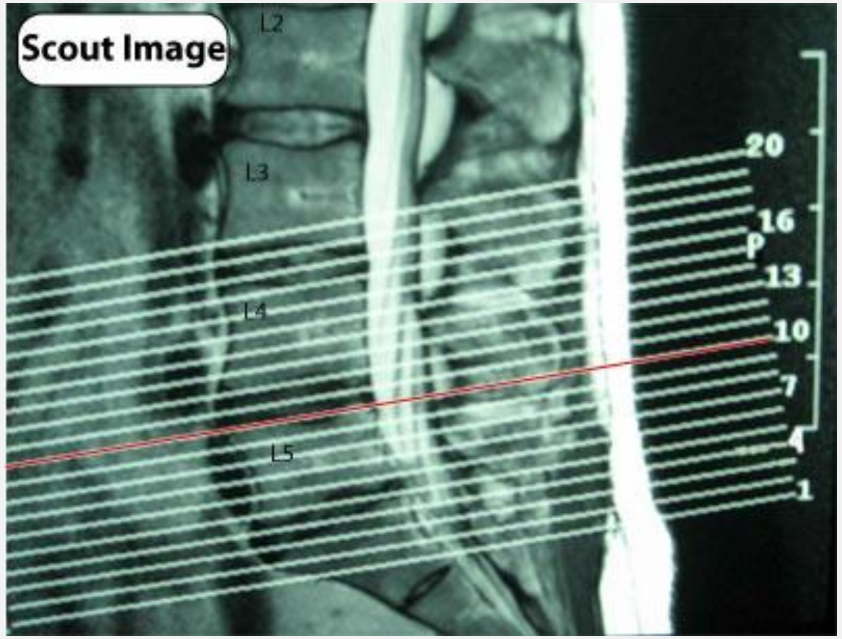


IMAGE MAGNIFICATION - 2 Ways

1. Uses only image data not raw data and has the effect of stretching the image to a larger size
   - Image distortion rises with an increase in the magnification factor
   - Can clarify the margins of an abnormality so a more accurate measurement can be taken

2. Uses raw or scan data and decreased DFOV
   - Image resolution is improved because smaller pixel sizes are used.
   - Image appears larger

Histogram

- **A graph that shows how frequently a range of CT numbers occurs within an ROI**