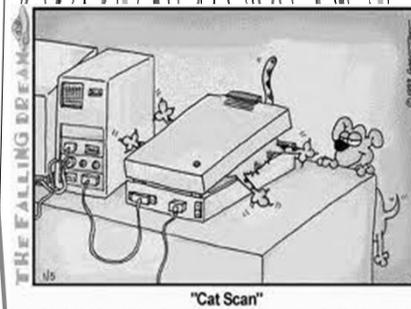


**READING HOSPITAL
SCHOOL OF HEALTH SCIENCES
MEDICAL IMAGING PROGRAM
BASICS OF CT—2021**

Digital Imaging-CT

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Digital Image Processing

ADC (Analog to Digital Converter)

- Converts analog information to digital, making the analog information useful to the computer
 - Digitization system
- Used for image processing and reconstruction in CT

Three steps needed to convert an analog image to digital:

- Scanning
- Sampling
- Quantization

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Scanning

For the picture to be digitized it is separated into small regions on a grid (matrix)

- Matrix comprised of rows and columns
- Pixels (Picture Element);
9 x 9 matrix = 81 pixels
 - 2-D representation of the corresponding tissue
- Each pixel is a CT number OR Hounsfield unit (HU)

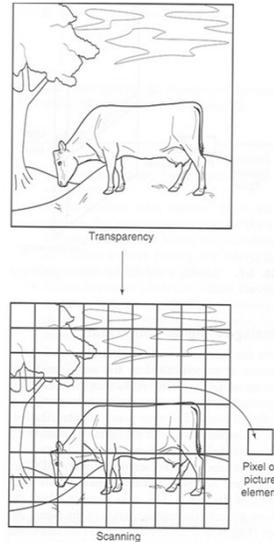


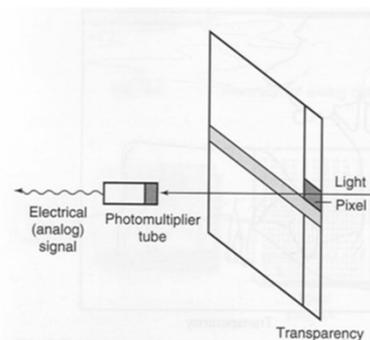
FIG. 3-5. Scanning is the first step in digitizing a picture.

3

Sampling

The brightness of each pixel is measured

- Light is transmitted through the pixel
- Light is detected by a photomultiplier tube (PMT)
- The output is an analog signal

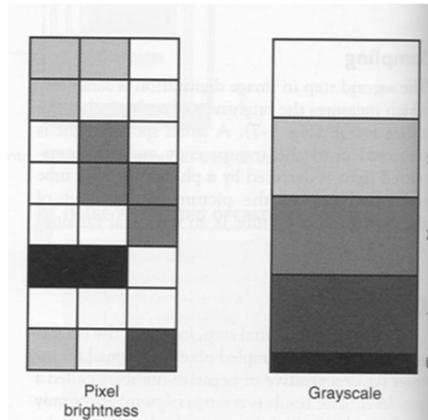


4

Quantization

Brightness value of the pixel is assigned

- Gray level
- Gray scale = number of gray levels
- Each pixel is a CT number
OR Hounsfield unit (HU)



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Imaging Characteristics

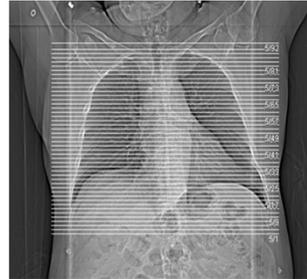
- Scan Field of View (SFOV)
- Display Field of View (DFOV)
- Matrix
- Pixel
- Voxel
- CT Numbers (HU)
- Slice Thickness
- Magnification



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Scan Field of View—SFOV

- Area to be imaged within the gantry; wherein raw data is collected
- Smaller the SFOV better the image resolution and faster scan time
- Determines number of detectors collecting data per scan



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Reconstruction or Display Field of View—DFOV

(also called---Zoom/Target)

- Determines how much of the collected raw data is used to create an image (and is reconstructed)
- Equal to or less than the size of the SFOV

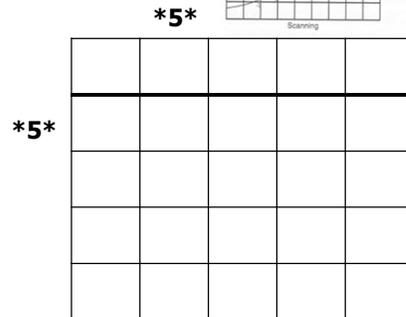


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Matrix

The computerized grid of data onto which the slice is placed for the purpose of reconstructing the density information

- CT image formatted on a matrix
- Common matrices are 512 x 512 and 1024 x 1024
- Matrix placed over the SFOV to cover the slice being imaged

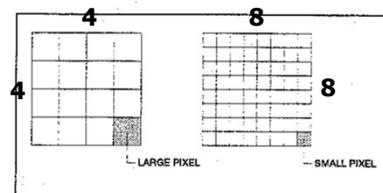


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Matrix

Effect of decreasing matrix size

- Larger pixels
- Decreased spatial resolution (detail)
- Decreased noise
 - Same number of photons used to cover fewer pixels
 - More photons per pixel = decreased noise

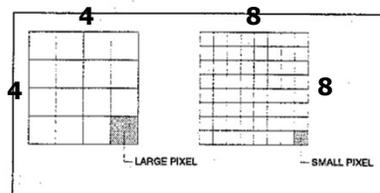


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Matrix

Effect of increasing matrix size

- Smaller pixels
- Increased spatial resolution (detail)
- Increased noise
 - Same number of photons used to cover a greater number of pixels
 - Loss of signal to each pixel = noise (graininess)
- Noise can be overcome by increasing mAs, but this increases patient dose



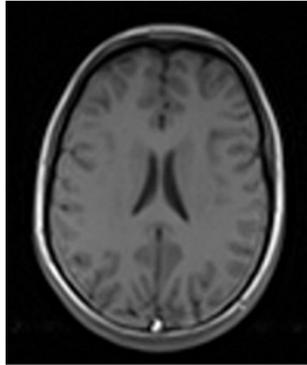
11

Matrix

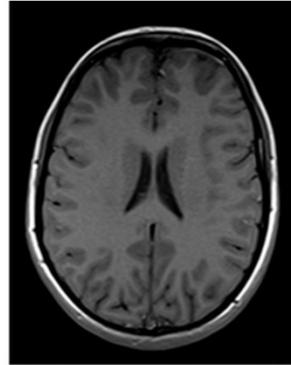
REVIEW:

- Relationship between matrix size to spatial resolution and noise is directly proportional
 - (Increased Matrix = Increased spatial resolution/noise)
 - (Decreased Matrix = Decreased spatial resolution/noise)
- Relationship between pixel size to spatial resolution and noise is inversely proportional
 - (Increase pixel size = decreased spatial resolution/noise)
 - (Decrease pixel size = increased spatial resolution/noise)

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Matrix size 128x128
Slice thickness 4mm
Low spatial resolution



Matrix size 256x256
Slice thickness 4mm
Good spatial resolution

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Pixels

- Pixel size related to the size of the matrix and the FOV
- Possible shades of gray determined by bits/pixel

- Pixel size (d) = FOV/matrix

Calculate the pixel size:

$$\text{FOV} = 48 \text{ cm} \quad \text{matrix} = 1024 \times 1024$$

$$d = 480\text{mm} / 1024$$

$$d = 0.469 \text{ mm}^2 = 0.47 \text{ mm}^2$$

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Pixels

- Compute the pixel size for the following characteristics of CT images used for brain scans:
 - a) FOV 20 cm, 120 x 120 matrix
 - b) FOV 20 cm, 512 x 512 matrix
 - c) FOV 36 cm, 512 x 512 matrix

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Pixels Pixel size (d) = FOV/matrix

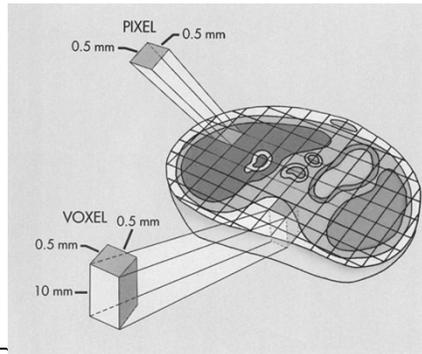
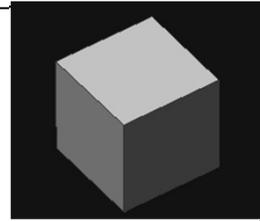
- a) FOV 20 cm, 120 x 120 matrix
 $200 \text{ mm} / 120 \text{ matrix} = 1.7 \text{ mm}^2$
- b) FOV 20 cm, 512 x 512 matrix
 $200 \text{ mm} / 512 \text{ matrix} = 0.4 \text{ mm}^2$
- c) FOV 36 cm, 512 x 512 matrix
 $360 \text{ mm} / 512 \text{ matrix} = 0.7 \text{ mm}^2$

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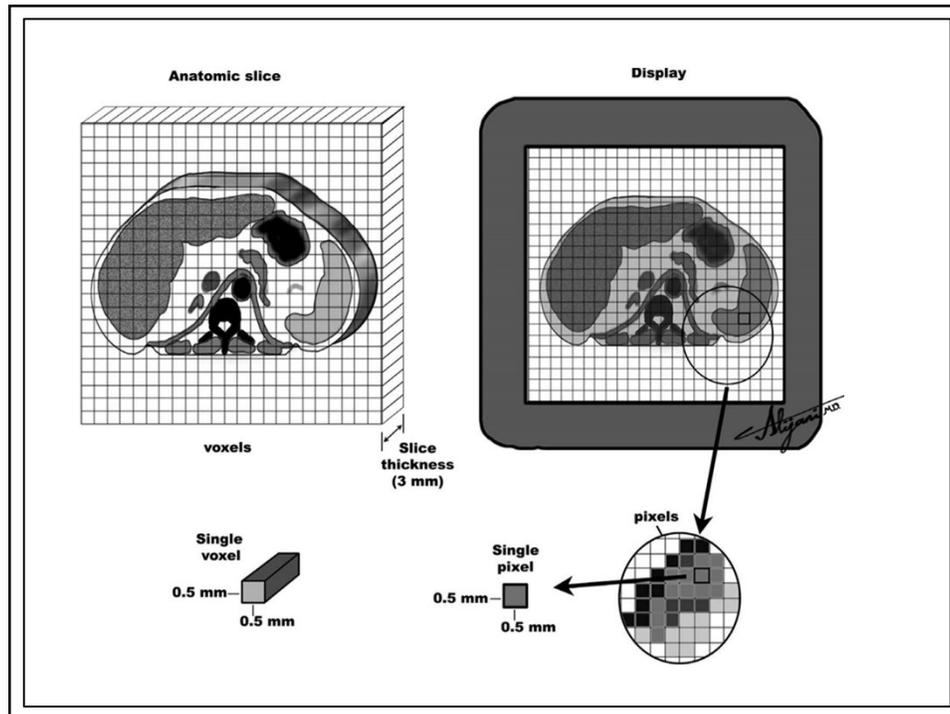
Voxels-Volume Element

- Tissue volume; 3-D
- Adds thickness
- Determined by multiplying the pixel size (squared) by the thickness of the CT image slice

$$(\text{Pixel size})^2 \times \text{slice thickness}$$



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Voxels-Volume Element

Question: If each of the three brain scans in the preceding problem was conducted at 5-mm slice thickness, what would be the respective voxel sizes?

(Pixel size)² x slice thickness

a)FOV 20 cm, 120 x 120 matrix

b)FOV 20 cm, 512 x 512 matrix

c)FOV 36 cm, 512 x 512 matrix

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Voxels-Volume Element

Answer:

a)FOV 20 cm, 120 x 120 matrix

$$200 \text{ mm} / 120 \text{ matrix} = 1.7 \text{ mm}^2$$

$$(1.7 \text{ mm})^2 \times 5 \text{ mm} = \mathbf{14.5 \text{ mm}^3}$$

b)FOV 20 cm, 512 x 512 matrix

$$200 \text{ mm} / 512 \text{ matrix} = 0.4 \text{ mm}^2$$

$$(0.4 \text{ mm})^2 \times 5 \text{ mm} = \mathbf{0.8 \text{ mm}^3}$$

c)FOV 36 cm, 512 x 512 matrix

$$360 \text{ mm} / 512 \text{ matrix} = 0.7 \text{ mm}^2$$

$$(0.7 \text{ mm})^2 \times 5 \text{ mm} = \mathbf{2.5 \text{ mm}^3}$$

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CT Numbers – Hounsfield Units (HU)

HU=the levels of brightness displayed on the monitor for each pixel

•Quantify the degree that a structure attenuates an x-ray beam

- Water = 0
- Dense (compact) Bone = 1,000 or higher
- Air = -1,000

$$\text{CT Number} = \frac{\mu_t - \mu_w}{\mu_w} \times 1000$$

μ_w = attenuation coefficient of water

μ_t = attenuation coefficient of the tissue

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So at 75 kVp for dense bone....

TABLE 28-3 Computed Tomography Number for Various Tissues and X-ray Linear Attenuation Coefficients at Four kVp Techniques

Tissue	CT Number	LINEAR ATTENUATION COEFFICIENT (CM ⁻¹)			
		75 kVp	100 kVp	125 kVp	150 kVp
Dense bone	3000	0.604	0.528	0.460	0.410
Muscle	50	0.273	0.237	0.208	0.184
White matter	45	0.245	0.213	0.187	0.166
Gray matter	40	0.243	0.212	0.184	0.163
Blood	20	0.241	0.208	0.182	0.163
Cerebrospinal fluid	15	0.240	0.207	0.181	0.160
Water	0	0.239	0.206	0.180	0.160
Fat	-100	0.213	0.185	0.162	0.144
Lungs	-200	0.111	0.093	0.081	0.072
Air	-1000	0.0005	0.0004	0.0003	0.0002

$$\frac{0.604 - 0.239}{0.239} \times 1000 = 1527.19$$

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CT Numbers – Hounsfield Units (HU)

Higher CT numbers –
assigned lighter shades
of gray (white)

Lower CT numbers –
assigned darker shades
of gray (black)

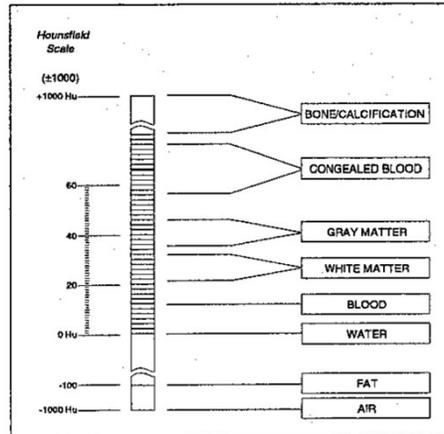


Fig. 3-3 Various tissues and where they are positioned on the Hounsfield scale.

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Attenuation

Reduction in the intensity of the beam as it passes through an object

- Some absorption, some scatter, some pass through
- Amount of attenuation depends on certain factors:
 - Density of tissue
 - Type of radiation used (kVp, mAs)**

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Attenuation

mAs** - current of electrons flowing from the cathode filament to the anode in the x-ray tube

- Determines the total number of x-ray photons that strike the detector
- Responsible for noise
 - Higher the mAs = lower the noise level of image
 - Increases the dose to the patient
 - Does not affect image contrast

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Attenuation

kVp** - Voltage across the anode and cathode determining the maximum energy of the x-ray photons

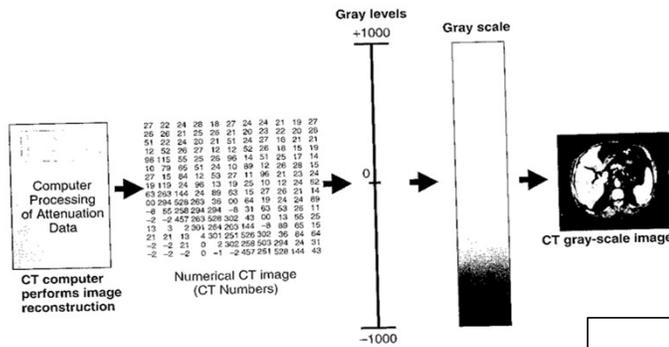
- *Increasing kVp*: increases energy of x-ray photons and the ability to penetrate the patient and strike the detector
- *Increasing kVp* = decreases image contrast
 - High energy photons will strike detectors and less likely to be absorbed by tissues

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CT Numbers - Hounsfield Units (HU)

Gray scale on an image can be adjusted by “windowing”

- The way an image can be viewed on a computer monitor
- Only 256 shades of gray viewable on monitor



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CT Numbers - Hounsfield Units (HU)

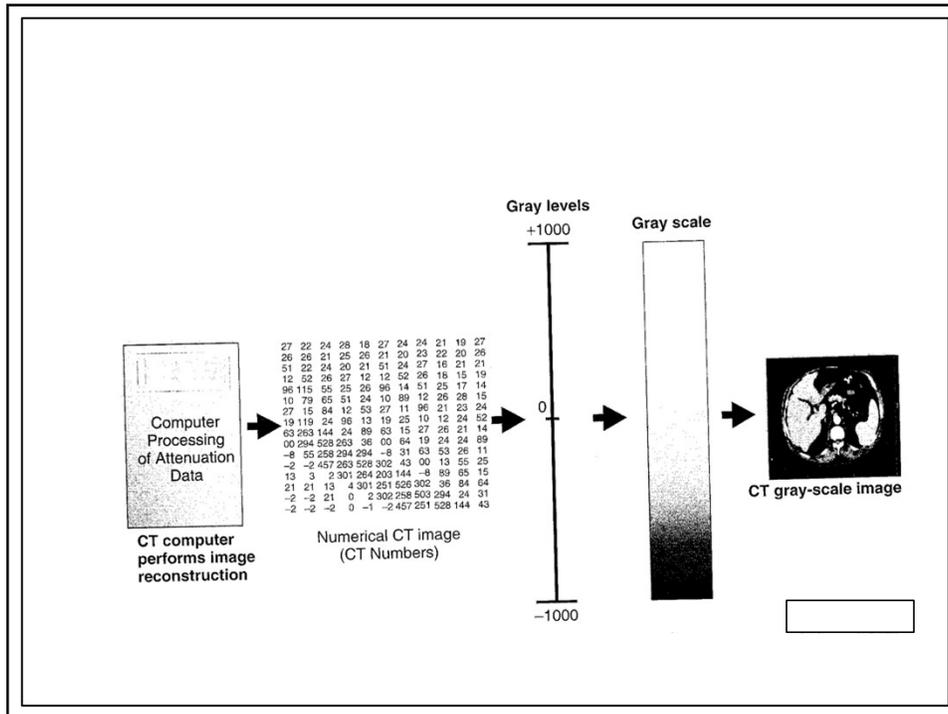
Window Level (wl) = HU value of the area of interest

- Selects the center CT value of the window width
- The center of the range

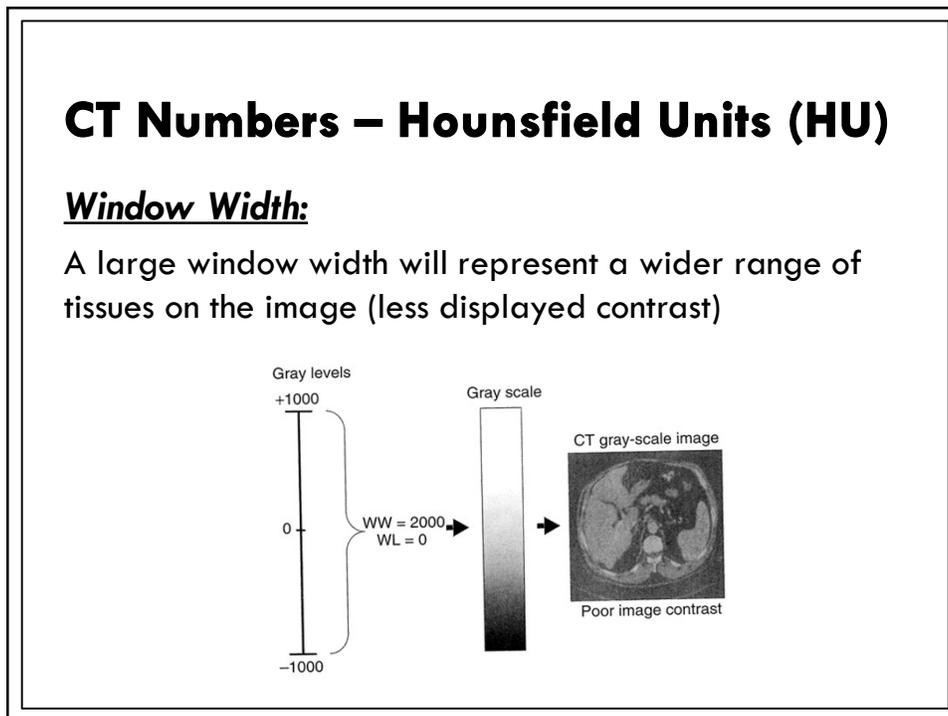
Window Width (ww) = range of grays (CT numbers) used

- Determines the number of Hounsfield units represented on a specific image
- All numbers above the range appear white; All numbers below the range will appear black

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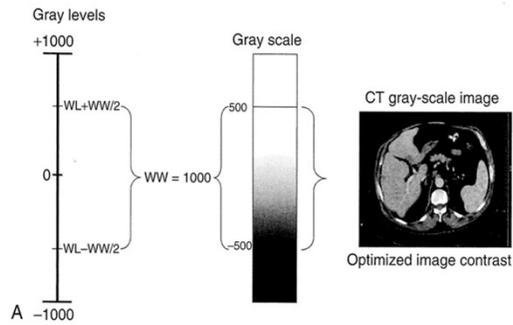


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CT Numbers – Hounsfield Units (HU)

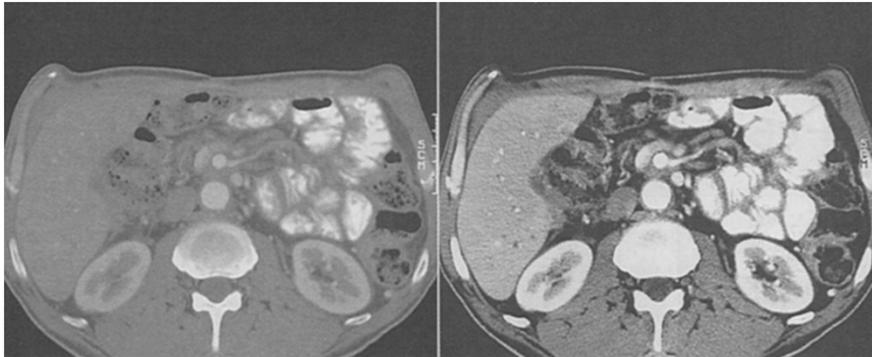
Window Width:

A small window width will have more of a distinct difference in grays (optimizes contrast)



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Wide vs. Narrow Window



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CT Numbers - Hounsfield Units (HU)

Calculations:

- Divide the window width in half
- **Subtract the quotient from the window level** (determines the lower limit of the range)
- **Add the quotient to the window level** to determine upper limit

WW=300 WL=200

$300/2=150$ (quotient)

$200-150=50$ -lower limit

$200+150=350$ -upper limit

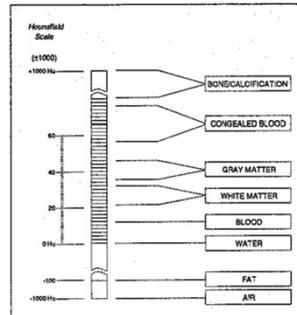


Fig. 3-3 Various tissues and where they are positioned on the Hounsfield scale.

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CT Numbers – Hounsfield Units (HU)

❖ Calculate the shades of gray:

ww=2,500 wl=350

$2500/2=1250$

$350-1250=-900$

$350+1250=1600$

Range of grays from -900 to 1,600

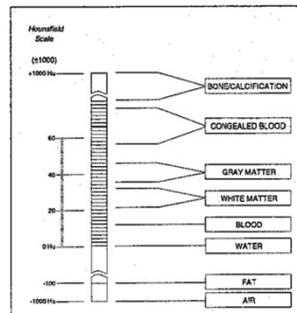


Fig. 3-3 Various tissues and where they are positioned on the Hounsfield scale.

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CT Numbers – Hounsfield Units (HU)

❖ Calculate the shades of gray:

$$ww=500 \quad wl=0$$

$$500/2=250$$

$$0-250= -250$$

$$0+250 = 250$$

Range of grays = -250 to 250

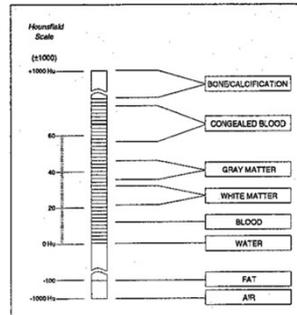


Fig. 3-3 Various tissues and where they are positioned on the Hounsfield scale.

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Slice Thickness

The width of the volume of tissue being examined (voxel)

Affects: Anatomical coverage, Noise in the image, Patient Dose

• Anatomical Coverage – Programmable

Slice Thickness = Thickness of the x-ray beam

Slices per rotation

20 mm thick x-ray beam 4 slices per rotation

$20\text{mm}/4 = 5 \text{ mm slice thickness}$

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Magnification

Permits viewer to enlarge part of the reconstructed image on the monitor for viewing or filming

- Allows for easier examination of image
- Enlarges the individual pixels
- Post-processing done to the image not the raw data

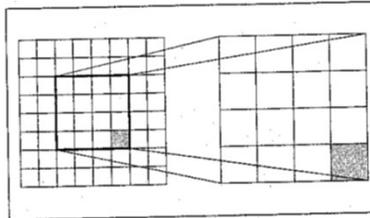


Fig. 3-11 Magnification simply takes a selected region of the image and enlarges the pixels for viewing and filming. The same amount of anatomy is represented by each pixel. Therefore, no change in spatial resolution results.

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JUST OUTSIDE THE BOX



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