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**Lecture No.: 1**

**Lecture Title: Introduction to Computed Tomography.**

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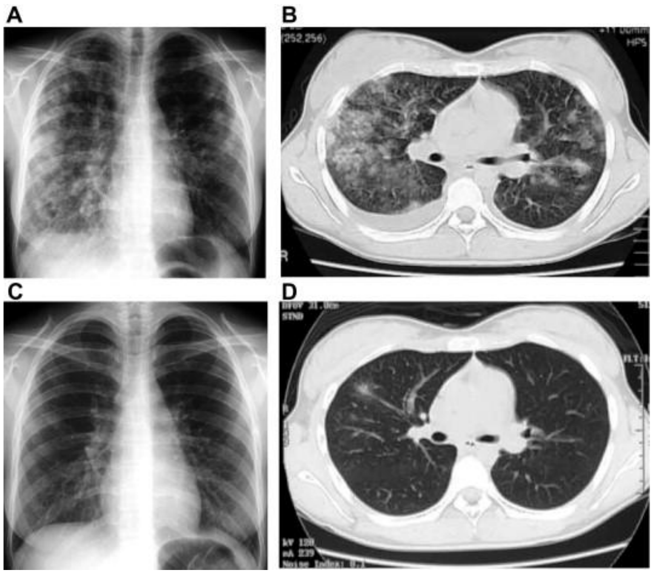
# Computed Tomography

- Conventional radiographs depict a three-dimensional object as a two-dimensional image. Another limitation of the conventional radiograph is its inability to distinguish between two tissues with similar densities.
- This results in overlying tissues being superimposed on the image, a major limitation of conventional radiography.
- Computed tomography (CT) overcomes this problem by scanning thin sections of the body with a narrow x-ray beam that rotates around the body, producing images of each cross section. The unique physics of CT allow for the differentiation between tissues of similar densities.
- The main advantages of CT over conventional radiography are in the elimination of superimposed structures, the ability to differentiate small differences in density of anatomic structures and abnormalities, and the superior quality of the images.

# Computed Tomography




# Computed Tomography

| Feature | Conventional Radiography (X-ray) | Computed Tomography (CT) |
|---|---|---|
| Imaging Principle | Uses ionizing radiation to produce a 2D image of the body. | Uses multiple X-ray beams from different angles to create 3D images of the body. |
| Image Type | 2D projection image | 3D cross-sectional images (slices) |
| Radiation Dose | Generally lower radiation dose compared to CT. | Higher radiation dose than conventional X-ray. |
| Image Quality | Can be limited by overlapping structures. | Provides better contrast and spatial resolution, allowing for better visualization of internal structures. |
| Cost | Typically less expensive than CT. | More expensive than conventional X-ray. |
| Applications | Chest X-ray, dental X-rays, bone fractures, foreign body detection. | Diagnosing various conditions such as cancer, heart disease, stroke, and internal injuries. |
| Preparation | Usually no special preparation required. | Patients may need to remove metal objects and may be given contrast agents. |

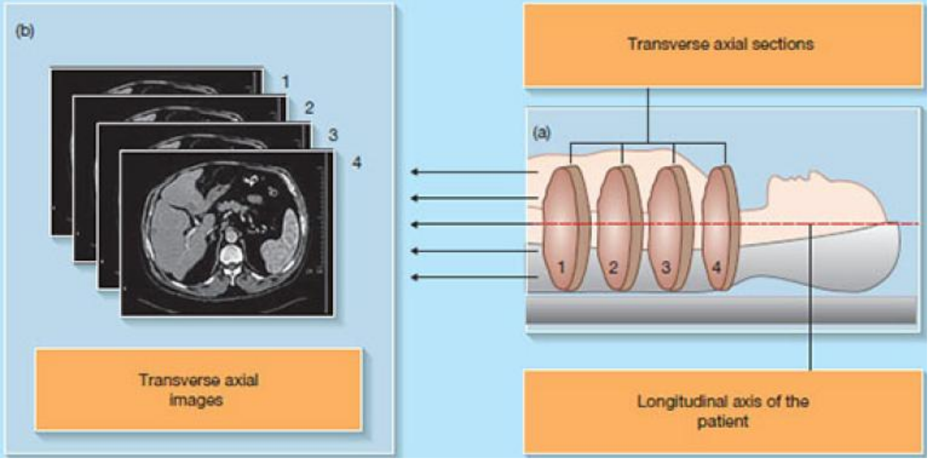
# Computed Tomography

CT image quality is typically evaluated using a number of criteria:

- Spatial resolution describes the ability of a system to define small objects distinctly.
- Low-contrast resolution refers to the ability of a system to differentiate, on the image, objects with similar densities.
- Temporal resolution refers to the speed that the data can be acquired. This speed is particularly important to reduce or eliminate artifacts that result from object motion, such as those commonly seen when imaging the heart.

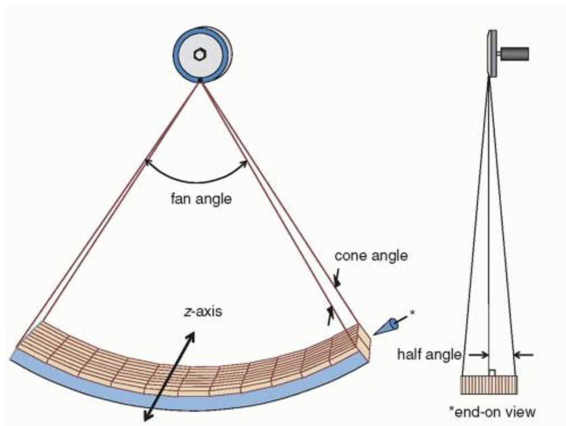
# Computed Tomography

- Computed tomography uses a computer to process information collected from the passage of x-ray beams through an area of anatomy.
- The images created are cross-sectional.

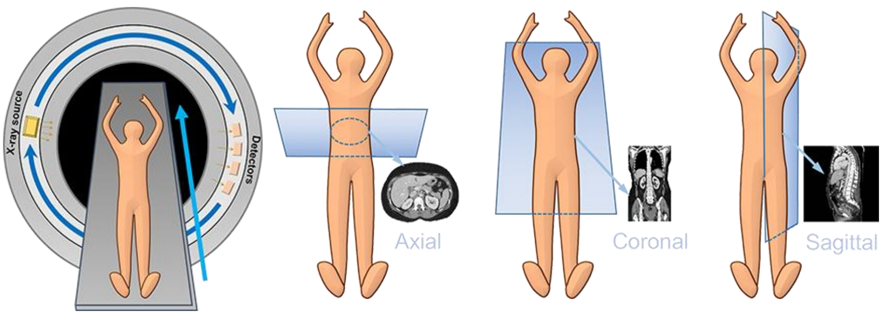


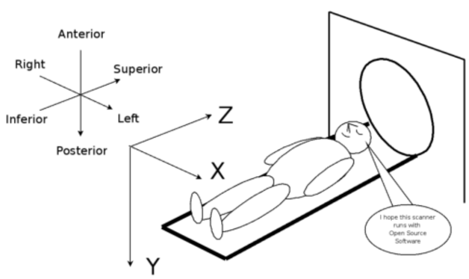
# Computed Tomography

- Each CT slice represents a specific plane in the patient's body. The thickness of the plane is referred to as the Z axis, which determines the thickness of the slices.
- The operator selects the thickness of the slice from the choices available on the specific scanner.
- Selecting a slice thickness limits the x-ray beam to pass only through this volume; hence, scatter radiation and superimposition of other structures are greatly diminished.
- Limiting the x-ray beam in this manner is accomplished by mechanical hardware that resembles small shutters, called collimators, which adjust the opening based on the operator's selection




# Computed Tomography



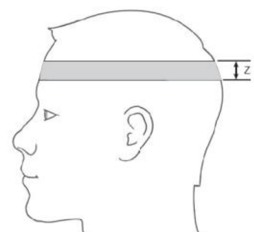




**FIGURE 1-1** The thickness of the cross-sectional slice is referred to as its *Z* axis.

# Computed Tomography

- The data are further sectioned into elements: width is indicated by X, while height is indicated by Y. Each one of these two-dimensional squares is a pixel (picture element).
- A composite of thousands of pixels creates the CT image that displays on the CT monitor.
- If the Z axis is taken into account, the result is a cube, rather than a square. This cube is referred to as a voxel (volume element).

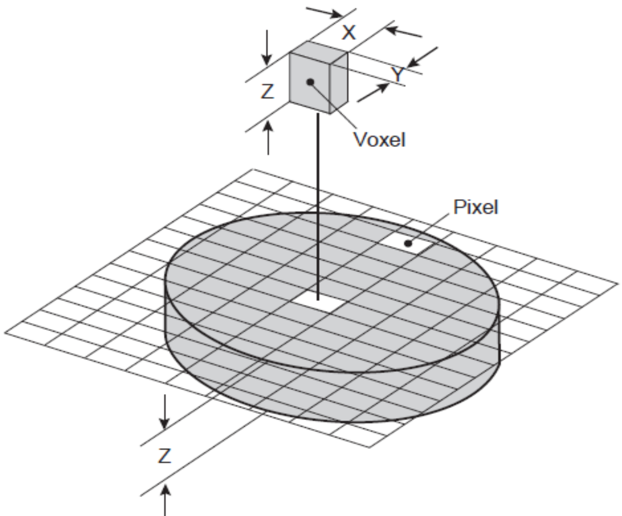



**FIGURE 1-2** The data that form the CT slice are sectioned into elements.

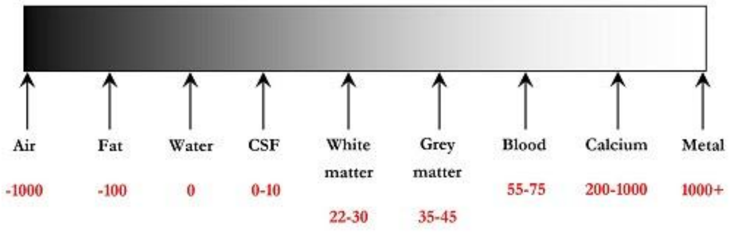
# Computed Tomography

***Beam attenuation***

- The structures in a CT image are represented by varying shades of gray.
- The creation of these shades of gray is based on basic radiation principles.
- An x-ray beam consists of bundles of energy known as photons. These photons may pass through or be redirected (i.e., scattered) by a structure, or my be may be absorbed by a given structure in varying amounts, depending on the strength (average photon energy) of the x-ray beam and the characteristics of the structure in its path.
- The degree to which a beam is reduced is a phenomenon referred to as attenuation.

# Computed Tomography

- In CT, the x-ray beam passes through the patient's body and is recorded by the detectors. The computer then processes this information to create the CT image.
- The quantities of x-ray photons that pass through the body determine the shades of gray on the image.
- X-ray photons that pass through objects unimpeded are represented by a black area on the image (the areas having low attenuation). While an X-ray beam that is completely absorbed by an object cannot be detected, the place on the image is white (the areas having high attenuation).
- Areas of intermediate attenuations are represented by various shades of gray.
- The number of the photons that interact depends on the thickness, density, and atomic number of the object.




# Computed Tomography

- The amount of the x-ray beam that is scattered or absorbed per unit thickness of the absorber is expressed by the linear attenuation coefficient, represented by the Greek letter μ.
- For example, if a 125-kVp x-ray beam is used, the linear attenuation coefficient for water is approximately 0.18 $cm^{-1}$. This means that about 18% of the photons are either absorbed or scattered when the X-ray beam passes through 1 cm of water.

**TABLE 1-1 Linear Attenuation Coefficients ($cm^{-1}$) at 125 kVp for Various Tissues**

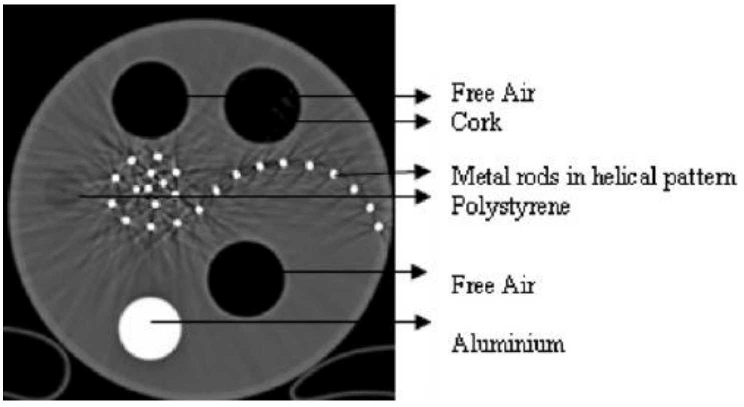
| Tissue | Linear Attenuation Coefficient ($cm^{-1}$) |
|---|---|
| Air | 0.0003 |
| Fat | 0.162 |
| Water | 0.180 |
| Cerebrospinal fluid | 0.181 |
| White matter | 0.187 |
| Gray matter | 0.184 |
| Blood | 0.182 |
| Dense bone | 0.46 |

# Computed Tomography

- In general, the attenuation coefficient decreases with increasing photon energy and increases with increasing atomic number and density.
- *If the kVp is kept constant*, the linear attenuation coefficient will be higher for bone than it would be for lung tissue.
- That is, bone attenuates more of the x-ray beam than does lung, allowing fewer photons to reach the CT detectors.
- Ultimately, this results in an image in which bone is represented by a lighter shade of gray than that representing lung.
- The CT image is a direct reflection of the distribution of linear attenuation coefficients. For soft tissues, the linear attenuation coefficient is roughly proportional to physical density.
- For this reason, the values in a CT image are sometimes referred to as density.

# Computed Tomography

- Metals are generally quite dense and have the greatest capacity for beam attenuation.
- Consequently, surgical clips and other metallic objects are represented on the CT image as white areas.
- Air (gas) has very low density, so it has little attenuation capacity.
- Air-filled structures (such as lungs) are represented on the CT image as black areas.



# Computed Tomography

**HOUNSFIELD UNITS**

- In CT, the beam attenuation capability of a given object can be quantified. Measurements are expressed in Hounsfield units (HU). These units are also referred to as CT numbers, or density values.
- Hounsfield arbitrarily assigned distilled water the number 0.
- He assigned the number 1000 to dense bone and −1000 to air.
- Objects with a beam attenuation less than that of water have an associated negative number. Conversely, substances with an attenuation greater than that of water have a proportionally positive Hounsfield value.

# Computed Tomography

- The Hounsfield unit of naturally occurring anatomic structures fall within this range of 1000 to −1000.
- The Hounsfield unit value is directly related to the linear attenuation coefficient: 1 HU equals a 0.1% difference between the linear attenuation coefficient of the tissue as compared with the linear attenuation coefficient of water.

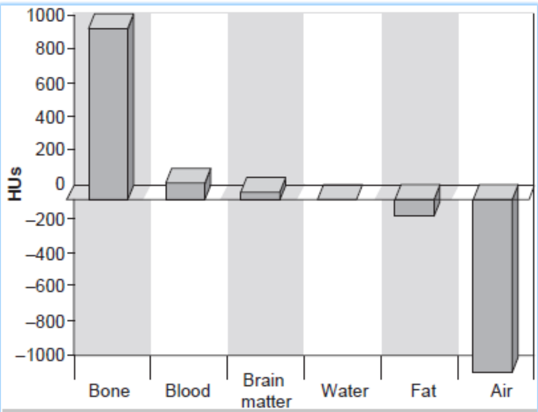



**FIGURE 1-5** Approximate Hounsfield units.

# Computed Tomography

**Example of Hounsfield Units and Linear Attenuation Coefficient:**
For a CT scan of the head, we compare the density of brain tissue and skull bone relative to water.
•**Reference Value:** We use the attenuation of Water ($\mu_{water}$) as our baseline. From the previous table, at 125 kVp, $\mu_{water} \approx 0.180\ cm^{-1}$.
**1. Linear Attenuation Coefficients (μ):**
•**Skull Bone:** It is dense and absorbs many X-rays. Let's assume $\mu_{bone} \approx 0.36\ cm^{-1}$.
•**Brain Tissue:** It is similar to water but slightly denser. Let's assume $\mu_{brain} \approx 0.187\ cm^{-1}$.
**2. Hounsfield Unit (HU) Formula:** $HU = 100\ X\ \frac{\mu_{tissue} - \mu_{water}}{\mu_{water}}$
**3. Calculation for Skull Bone:**
•**Difference:** 0.36−0.180=0.180
•**Ratio:** 0.180/0.180=1.0
•**Result:** 1000×1.0=+1000 HU *(This accurately represents dense bone).*
**4. Calculation for Brain Tissue:**
•**Difference:** 0.187−0.180=0.007
•**Ratio:** 0.007/0.180≈0.0388
•**Result:** 1000×0.0388≈+39 HU *(This accurately represents normal brain tissue).*

# Computed Tomography

**Homework: Calculating HU for Fat vs. Dense Bone**

**Scenario:** You are scanning a patient's abdomen. We need to determine the Hounsfield Units for Fat (which is less dense than water) and Dense Bone (which is much denser). Given Values (Table 1-1):

- Reference ($\mu_{water}$): $0.180\ cm^{-1}$
- Target A ($\mu_{fat}$): $0.162\ cm^{-1}$
- Target B ($\mu_{bone}$): $0.460\ cm^{-1}$


THANK YOU