

Introduction to Computed Tomography (CT)

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Designed as a concise, study-friendly overview.

1. What Is Computed Tomography?

- **Definition:** A medical imaging modality that creates cross-sectional (tomographic) images of the body by reconstructing multiple X-ray projections taken around the patient.
- **Key Idea:** Instead of a single 2D X-ray image, CT provides a series of thin “slices” that can be stacked to form a 3D representation.
- **Typical Uses:**
 - Trauma assessment (head, chest, abdomen)
 - Oncology (tumor detection, staging, treatment monitoring)
 - Vascular imaging (angiography, pulmonary embolism)
 - Surgical planning and guidance

2. Basic Physical Principles

Concept	Description	Relevance to CT
X-ray Attenuation	Photons are absorbed or scattered as they pass through matter; attenuation depends on density and atomic number.	Determines contrast between different tissues.
Beer-Lambert Law	$I = I_0 \cdot e^{-\mu x}$ where I = transmitted intensity, I_0 = incident intensity, μ = linear attenuation coefficient, x = path length.	Basis for converting raw detector signals to attenuation values.
Radon Transform	Mathematical operation that integrates a function over straight lines; each X-ray projection is a line integral of attenuation.	The set of projections collected at many angles constitutes the Radon data used for reconstruction.
Filtered Back-Projection (FBP)	Classical reconstruction algorithm: each projection is filtered (high-frequency boost) then back-projected across the image space.	Fast, widely used in clinical scanners.

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Concept	Description	Relevance to CT
Iterative Reconstruction (IR)	Starts with an initial guess, simulates projections, compares to measured data, and updates the guess repeatedly.	Reduces noise and radiation dose; increasingly common.

3. System Components

1. X-ray Tube

- Generates a fan- or cone-shaped beam.
- Adjustable tube voltage (kVp) and current (mA) to control photon energy and flux.

2. Gantry

- Rotating frame that holds the X-ray tube and detector array.
- Typical rotation speeds: 0.3–1.0s per rotation (fast for cardiac CT).

3. Detector Array

- Scintillator + photodiodes (or solid-state detectors) that convert X-ray photons to electrical signals.
- Number of detector rows defines “slices per rotation” (e.g., 64-row, 128-row, 256-row, 320-row, or > 640 for ultra-high-resolution).

4. Patient Table (Couch)

- Moves the patient longitudinally (helical/spiral scanning) or steps between rotations (axial scanning).

5. Computer System

- Controls acquisition parameters.
 - Performs raw data correction (gain, offset, scatter, beam-hardening).
 - Executes reconstruction algorithms and displays images.
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4. Scanning Modes

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Mode	Description	Typical Applications
Axial (Step-and-Shoot)	Table stops; a single rotation acquires one slice.	High-resolution brain, temporal bone imaging.
Helical (Spiral)	Table continuously translates while the gantry rotates, producing	