CT Scan Principles

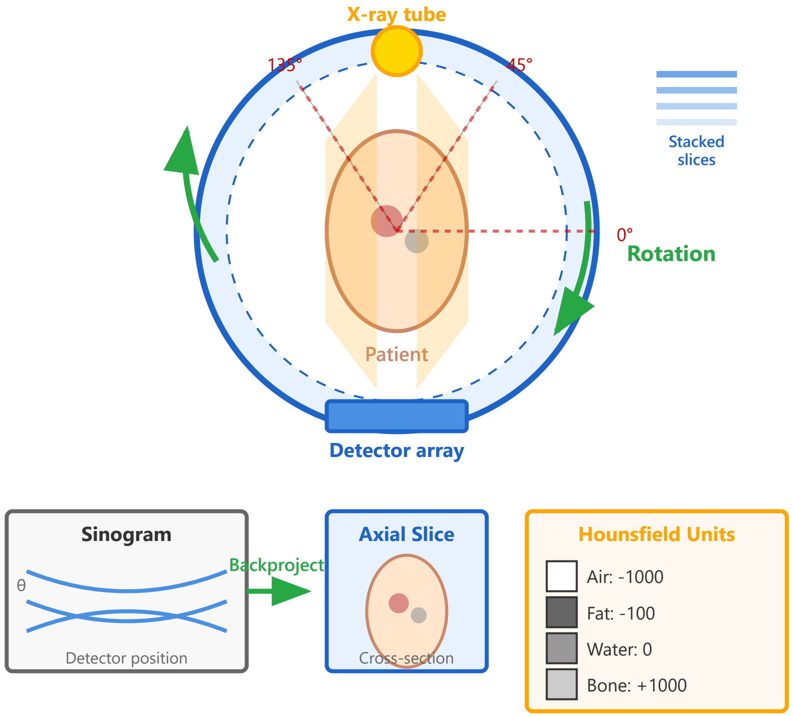
Tomographic reconstruction
Multiple X-ray projections create 3D volume

Hounsfield units
Standardized tissue density scale

Spiral/helical CT
Continuous rotation and table movement

Dose reduction strategies
Iterative reconstruction, tube modulation

Contrast protocols
IV contrast timing for specific applications



Tomographic Reconstruction

Principle

Tomographic reconstruction is the mathematical process of creating cross-sectional images from X-ray projection data acquired at multiple angles around the patient. This technique allows visualization of internal structures without overlapping anatomy.

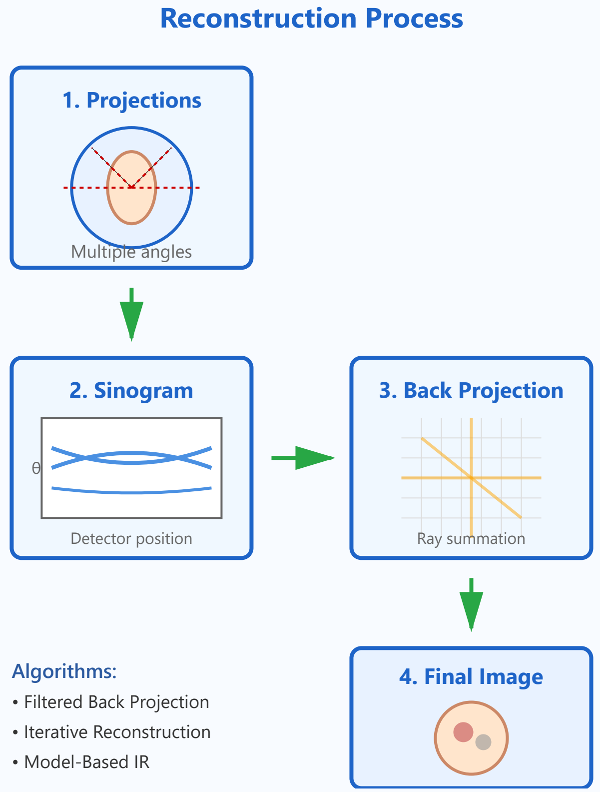
Reconstruction Algorithms

- **Filtered Back Projection (FBP):** Traditional method that applies mathematical filters to projection data before backprojecting into image space
- **Iterative Reconstruction:** Modern approach that uses statistical models to improve image quality and reduce noise
- **Model-Based Reconstruction:** Advanced technique incorporating system physics and noise characteristics

> **Key Point:** Modern CT scanners acquire hundreds to thousands of projections per rotation, enabling high-resolution 3D volume reconstruction with submillimeter detail.

Clinical Significance

The quality of reconstruction directly impacts diagnostic accuracy. Advanced algorithms can reduce artifacts, improve contrast resolution, and enable lower radiation doses while maintaining image quality.



2 Hounsfield Units (HU)

Definition

Hounsfield Units (HU) are standardized measurements of radiodensity used in CT imaging. Named after Sir Godfrey Hounsfield, the inventor of CT, this scale provides quantitative assessment of tissue attenuation relative to water.

The HU Scale

The scale is defined such that water has a value of 0 HU, and air has a value of -1000 HU. The mathematical formula is:

$$HU = 1000 \times (\mu - \mu_{water}) / \mu_{water}$$

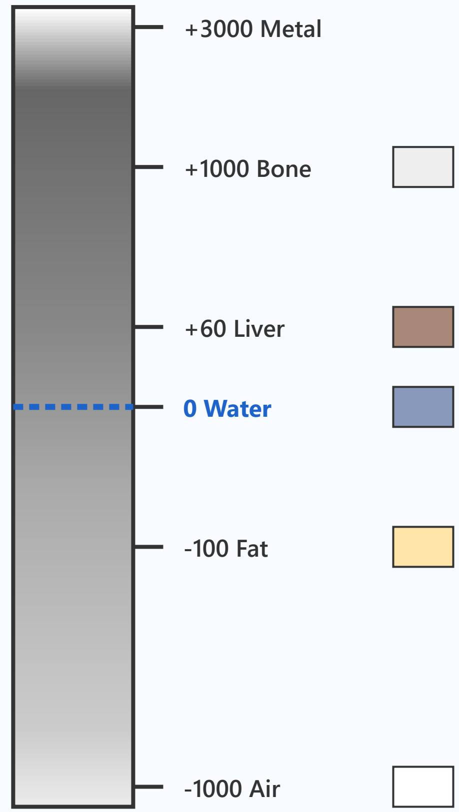
where μ is the linear attenuation coefficient of the tissue.

Common HU Ranges

- **Air:** -1000 HU (lungs, bowel gas)
- **Fat:** -100 to -50 HU (adipose tissue)
- **Water:** 0 HU (CSF, simple cysts)
- **Soft tissue:** +40 to +80 HU (liver, spleen, muscle)
- **Bone:** +400 to +1000 HU (cortical bone can exceed +1000)
- **Metal:** >+1000 HU (surgical implants, dental fillings)

> **Clinical Application:** HU values help characterize lesions, differentiate tissues, and diagnose conditions such as hemorrhage, calcifications, and fat-containing masses.

Hounsfield Unit Scale



Common Window Settings:

Brain: W80/L40 | Lung: W1500/L-600 | Bone: W2000/L300

Window Settings

Window width and level settings determine which range of HU values are displayed, allowing optimization for viewing different tissues (e.g., bone windows, lung windows, soft tissue windows).

3 Spiral/Helical CT

Technology Overview

Spiral (or helical) CT represents a major advancement in CT imaging where the X-ray tube rotates continuously while the patient table moves through the gantry at a constant speed. This creates a helical path of data acquisition around the patient.

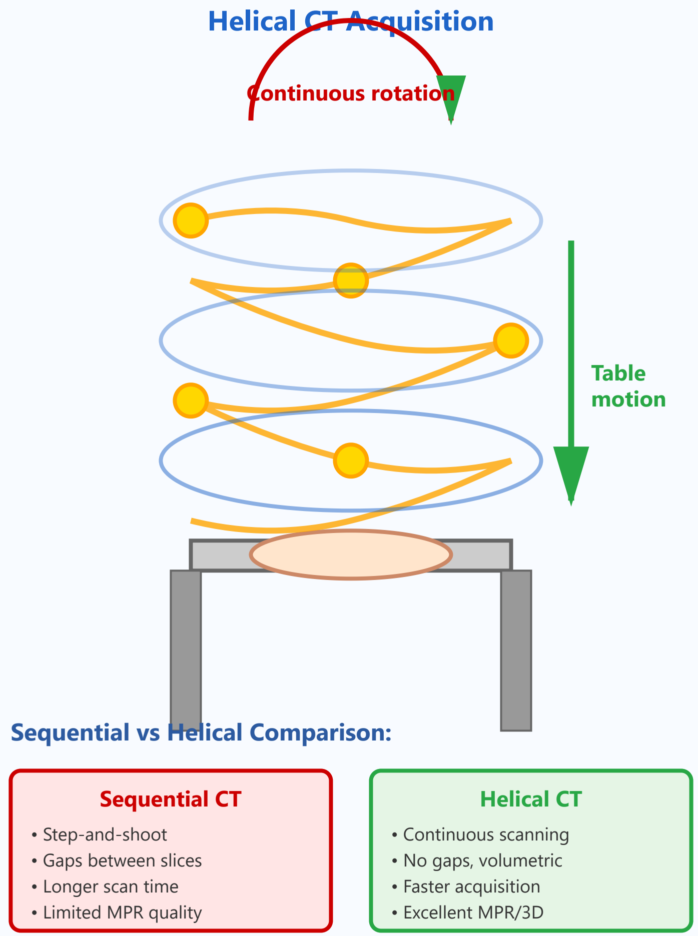
Key Parameters

- **Pitch:** The ratio of table movement per rotation to the beam width. Higher pitch = faster scanning but potentially lower image quality
- **Rotation time:** Time for one complete revolution (typically 0.3-1.0 seconds)
- **Slice thickness:** Can be retrospectively adjusted due to volumetric data acquisition

Advantages

- Faster scan times, reducing patient motion artifacts
- Continuous volumetric data acquisition
- Improved contrast medium utilization
- Ability to create multiplanar reformations (MPR)
- Better detection of small lesions
- Reduced respiratory artifacts

Clinical Impact: Helical CT enables CT angiography, multi-phase liver imaging, and comprehensive trauma surveys in a single breath-hold, revolutionizing emergency and vascular imaging.



Multi-Detector CT (MDCT)

Modern spiral CT scanners use multiple detector rows (16, 64, 128, or more), allowing simultaneous acquisition of multiple slices per rotation, further increasing speed and resolution.

4 Dose Reduction Strategies

ALARA Principle

CT imaging follows the ALARA principle (As Low As Reasonably Achievable), balancing diagnostic image quality with radiation dose. Modern CT scanners incorporate multiple dose reduction technologies.

Key Dose Reduction Techniques

1. Automatic Tube Current Modulation (ATCM):

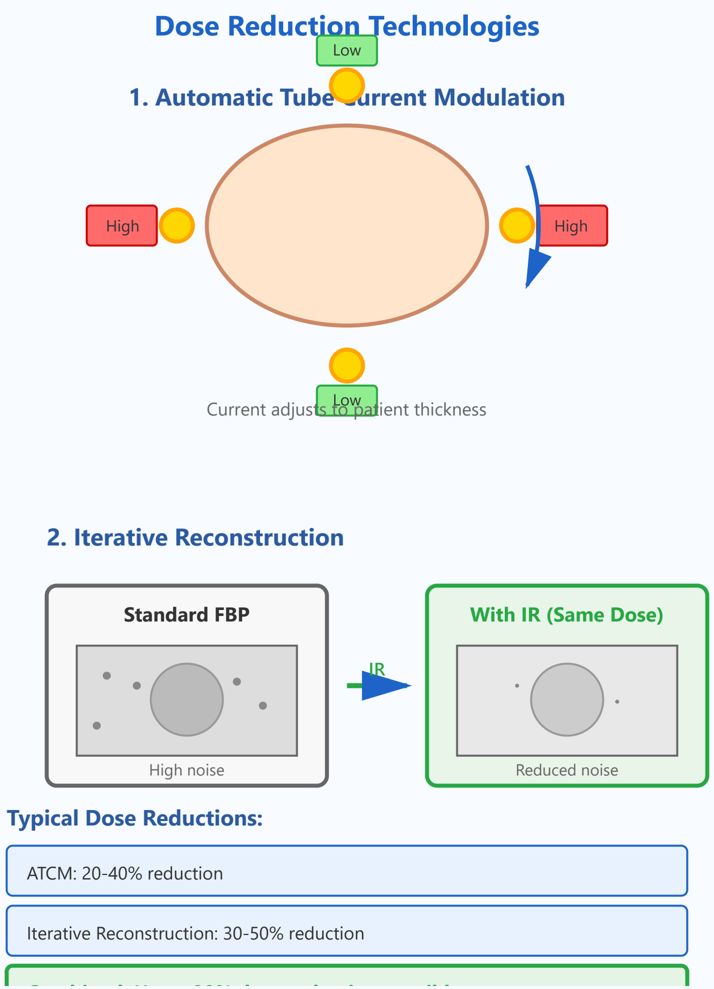
- Adjusts X-ray output based on patient size and anatomy
- Angular modulation: varies current around the patient's circumference
- Longitudinal modulation: adjusts current along the patient's length
- Can reduce dose by 20-40% without compromising image quality

2. Iterative Reconstruction (IR):

- Advanced algorithms that reduce image noise
- Enables lower tube current while maintaining diagnostic quality
- Types include ASIR, SAFIRE, iDose, and ADMIRE
- Can reduce dose by 30-50% compared to FBP

3. Organ-Specific Dose Reduction:

- Bismuth breast shields for chest CT
- Eye lens protection for head CT
- Gonadal shielding when appropriate



Important: Modern dose reduction can achieve up to 80% dose reduction in some protocols while maintaining diagnostic quality. Pediatric protocols require special attention to dose optimization.

Other Strategies

- Appropriate protocol selection
- Limiting scan range to the region of interest
- Using low-dose screening protocols when appropriate
- Regular quality assurance and dose monitoring

5 Contrast Protocols

Intravenous Contrast Agents

Iodinated contrast media enhance the visibility of blood vessels and tissues with increased vascularity. Proper timing and injection protocols are critical for optimal diagnostic imaging.

Contrast Phases

1. Non-contrast Phase:

- Baseline imaging before contrast administration
- Essential for detecting calcifications, hemorrhage, and baseline attenuation

2. Arterial Phase (25-35 seconds):

- Peak arterial enhancement
- Used for: CT angiography, hypervascular tumors, acute arterial bleeding
- Critical for evaluating arterial anatomy and pathology

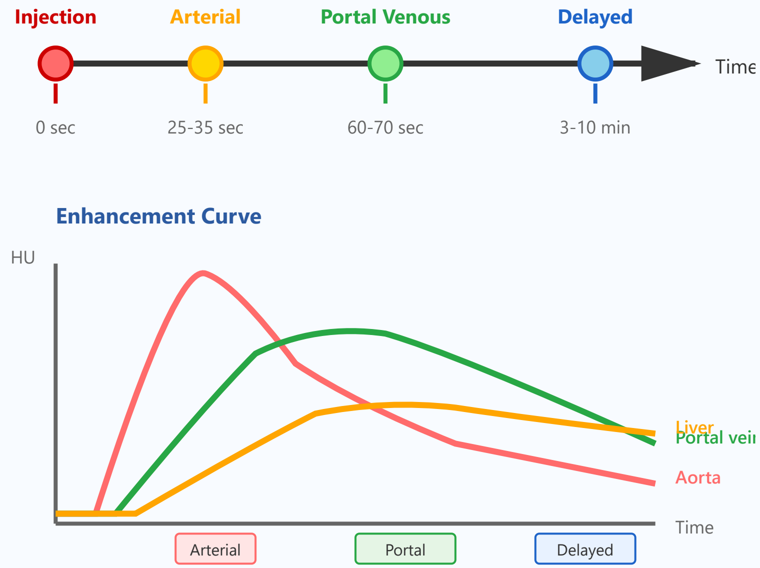
3. Portal Venous Phase (60-70 seconds):

- Optimal for abdominal organ parenchyma
- Most commonly used phase for routine abdominal CT
- Good visualization of liver, spleen, kidneys, and pancreas

4. Delayed Phase (3-10 minutes):

- Used for urinary tract evaluation (CT urography)
- Detection of urothelial tumors
- Characterization of certain lesions (e.g., cholangiocarcinoma)

Contrast Enhancement Phases



Common Clinical Protocols:

CT Angiography (CTA)
Arterial phase only, bolus tracking, 4-5 mL/s injection rate

Triple Phase Liver CT
Arterial, portal venous, delayed - for HCC characterization

Pulmonary Embolism Protocol
Timing for pulmonary artery, 4 mL/s, bolus tracking at PA

Routine Abdomen/Pelvis
Portal venous phase (60-70 sec), 2-3 mL/s

Safety Consideration: Screen patients for renal function (eGFR), previous contrast reactions, and metformin use. Ensure adequate hydration before and after contrast administration.

Injection Parameters

- **Volume:** Typically 80-150 mL, weight-based
- **Injection rate:** 2-5 mL/s depending on protocol
- **Concentration:** Usually 300-370 mg iodine/mL
- **Saline flush:** 30-50 mL to push contrast bolus

Special Protocols

- **CT Angiography:** High injection rate (4-5 mL/s), bolus tracking
- **Triple phase liver:** Arterial, portal venous, and delayed phases
- **CT Urography:** Split bolus or excretory phase imaging
- **Pulmonary embolism:** Timing for optimal pulmonary artery opacification