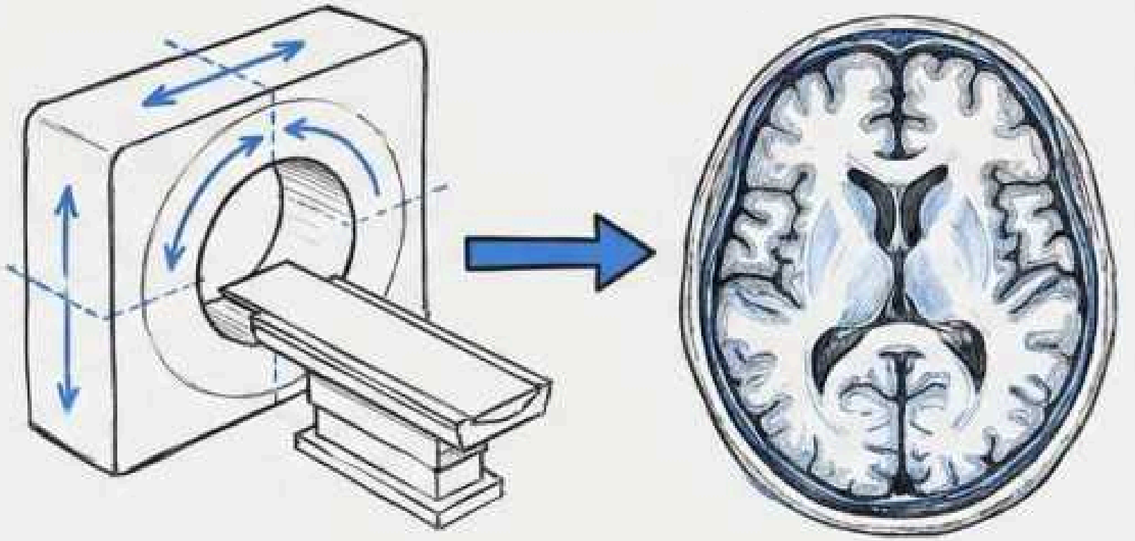
The Invention of CT: Erasing the Shadows

$$R_f(p,\xi) = \int_{-\infty}^{+\infty} f(p\cos\xi - s\sin\xi, p\sin\xi + s\cos\xi)\,ds$$

1960s: Mathematics of image reconstruction developed independently by Allan Cormack.



1971: First patient brain scan by Godfrey Hounsfield, an EMI engineer.

1979: Joint Nobel Prize in Medicine awarded to Cormack and Hounsfield.

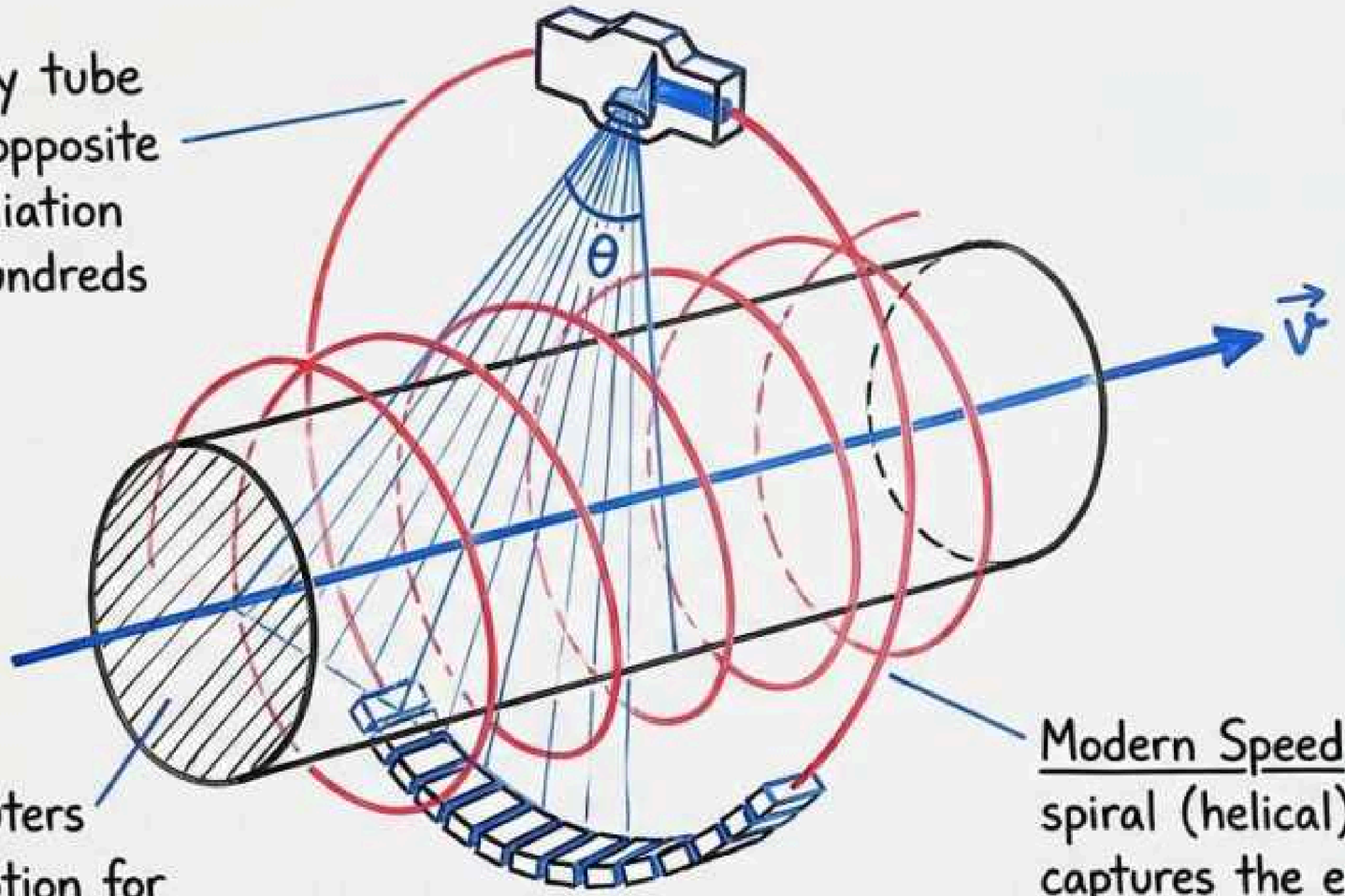
The Breakthrough: The first technique to reveal the body's interior in clean cross-sectional slices, permanently eliminating overlapping X-ray shadows.

Gemini Notebook

Physics in Motion: The Helical Scan

¶ 2.2

Acquisition: An X-ray tube rotates rapidly while opposite detectors measure radiation transmission across hundreds of angles.



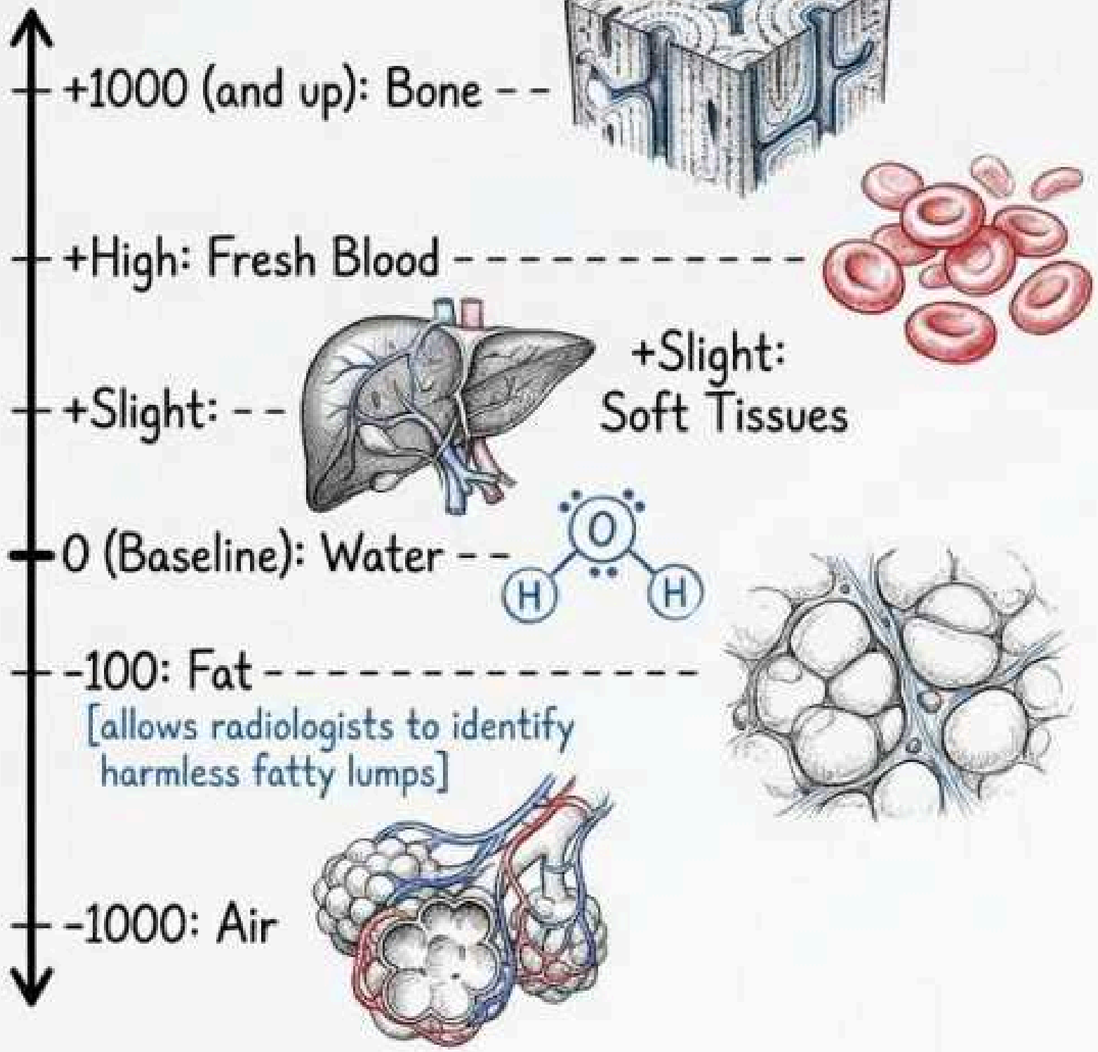
Reconstruction: Computers calculate tissue absorption for each tiny volume (voxel) to create cross-sectional slices.

Modern Speed: Continuous spiral (helical) movement captures the entire chest or abdomen in mere seconds.

Gemini Notebook

Quantifying Tissue: The Hounsfield Scale

$$HU = 1000 \times \frac{\mu - \mu_{water}}{\mu_{water}}$$



Gemini Notebook

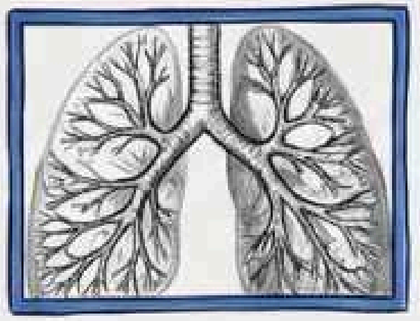
Windowing: Overcoming Visual Limits

¶ 2.4

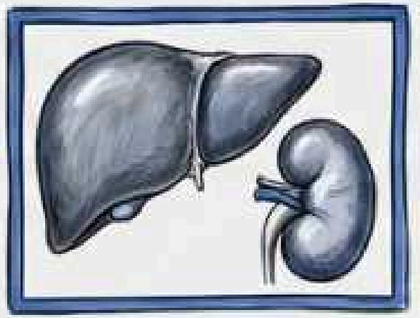
The Physiological Limit:
The human eye can distinguish only a limited number of grey shades.

The Solution:
Radiologists select specific HU ranges to spread across the grey scale.

$$\begin{bmatrix} 1024, & 1030, & 998 \\ 1020, & 1005, & 990 \\ 1015, & 1000, & 995 \\ \vdots & \vdots & \vdots \\ 1020, & 1005, & 990 \\ 1000, & 990, & 990 \\ 990, & 980, & 985 \\ 980, & 970, & 980 \\ \vdots & \vdots & \vdots \\ 950, & 960, & 975 \end{bmatrix}$$



Lung Window:
Maximizes contrast for the fine structure of the lungs.



Soft Tissue Window:
Optimized for viewing solid organs.



Bone Window:
High contrast to identify fractures.

Gemini Notebook

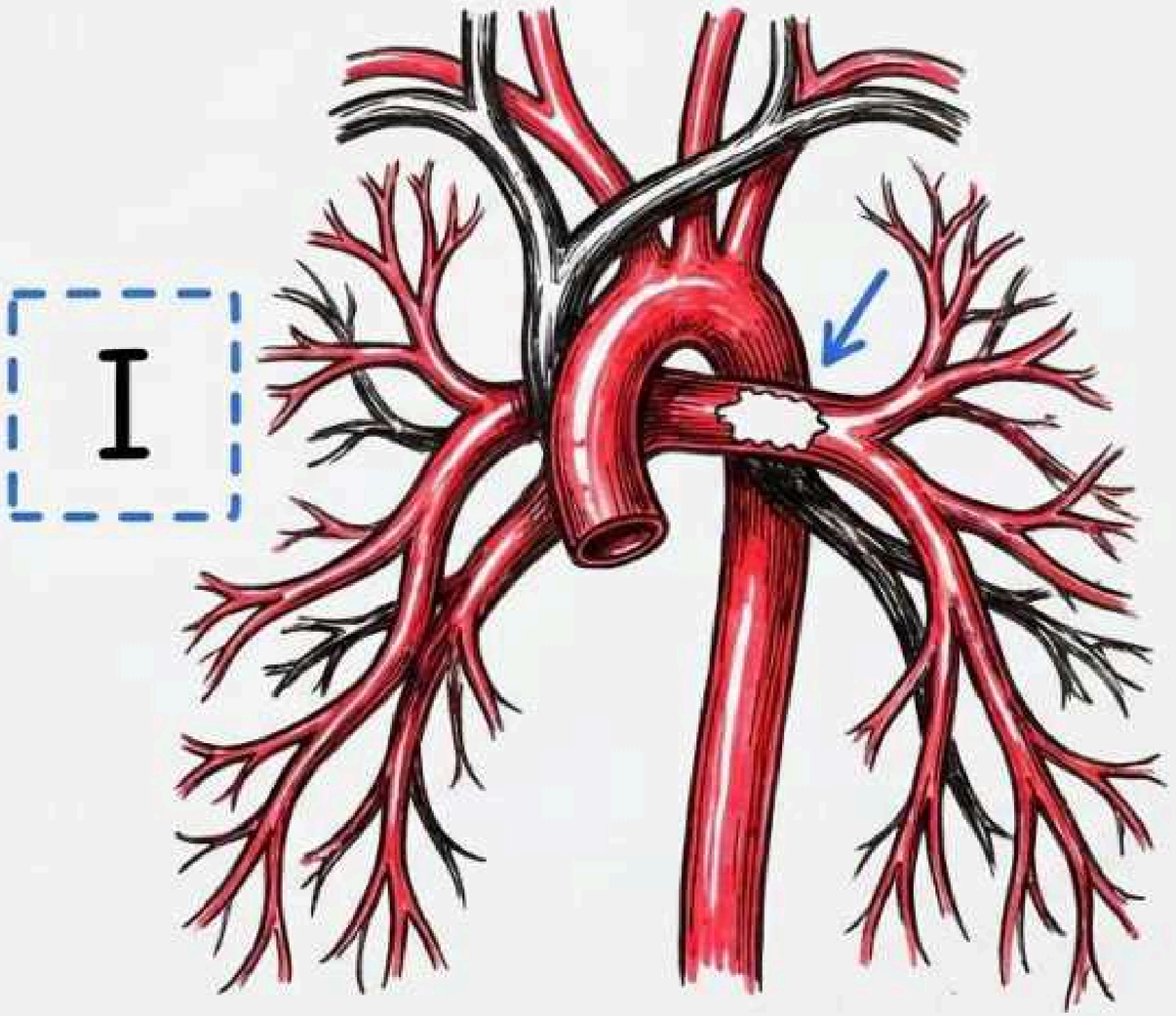
Contrast Agents: Illuminating the Vasculature

¶ 2.5

Mechanism: Intravenous iodine-based agents brighten blood vessels and well-supplied tissues.

CT Angiography: Scans perfectly timed to catch contrast in arteries reveal narrowed vessels or blood clots in the lungs.

Risk Profile: Carries a small risk of allergic-type reactions. Historical concerns regarding kidney damage are now considered overestimated based on recent evidence.

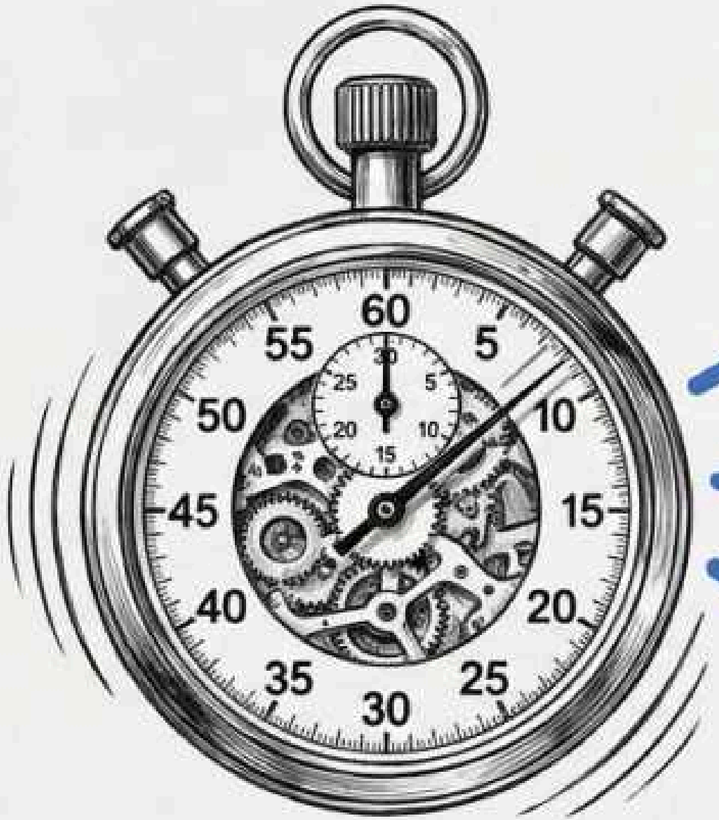


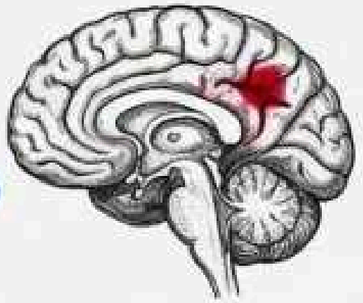
Gemini Notebook

The First Line in Emergencies

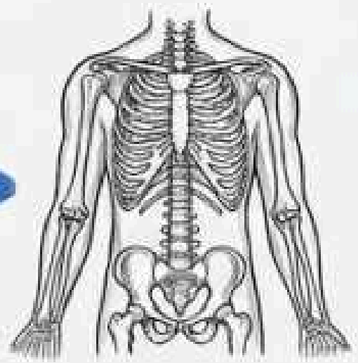
¶ 2.6

Why CT? Unmatched speed and wide availability make it the immediate go-to test in the ER.

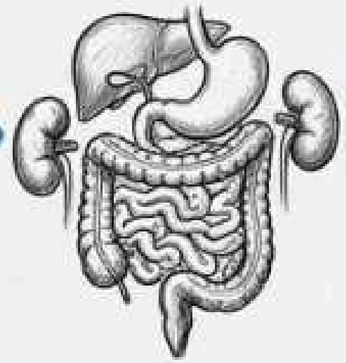




Suspected Stroke (Brain):
Rapidly identifies internal bleeding, dictating if clot-dissolving treatment can be safely given.



Major Trauma (Whole Body):
Rapid, comprehensive injury identification.



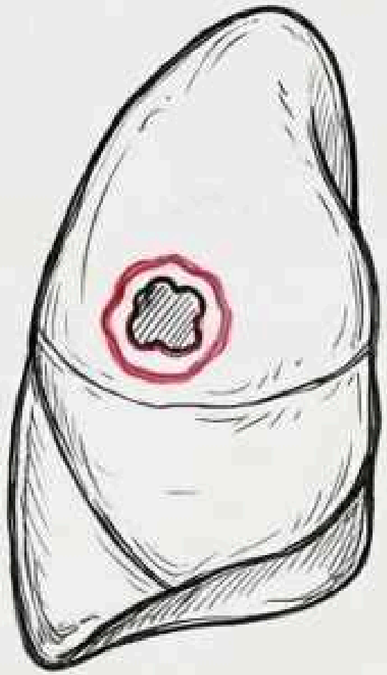
Acute Abdomen:
Readily identifies appendicitis, kidney stones, bowel blockages, and many cancers.

Gemini Notebook

Screening and Oncology

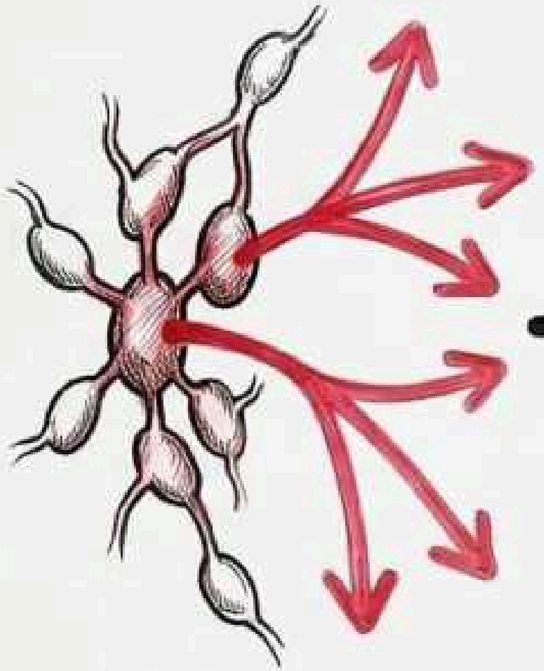
¶ 2.7

Screening:



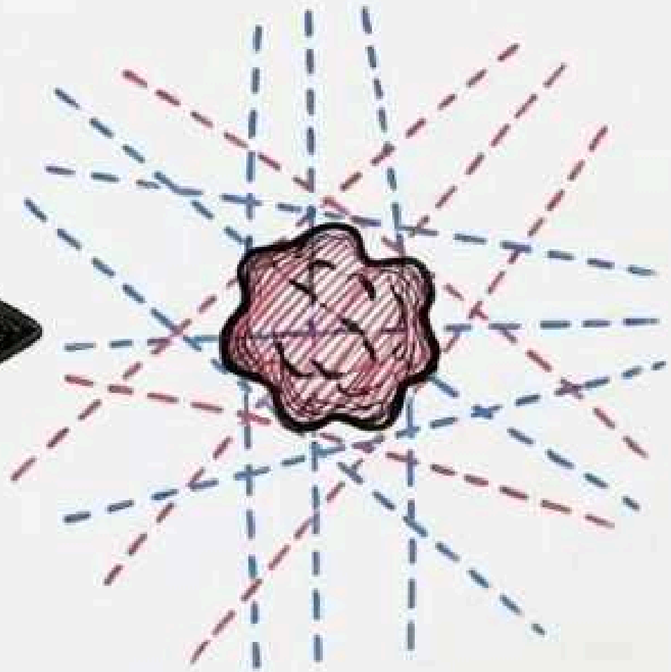
Low-dose chest CTs reduce lung cancer deaths in long-term heavy smokers (proven by the large 2011 National Lung Screening Trial).

Staging:



Accurately measures the precise spread of many cancers.

Treatment Planning:

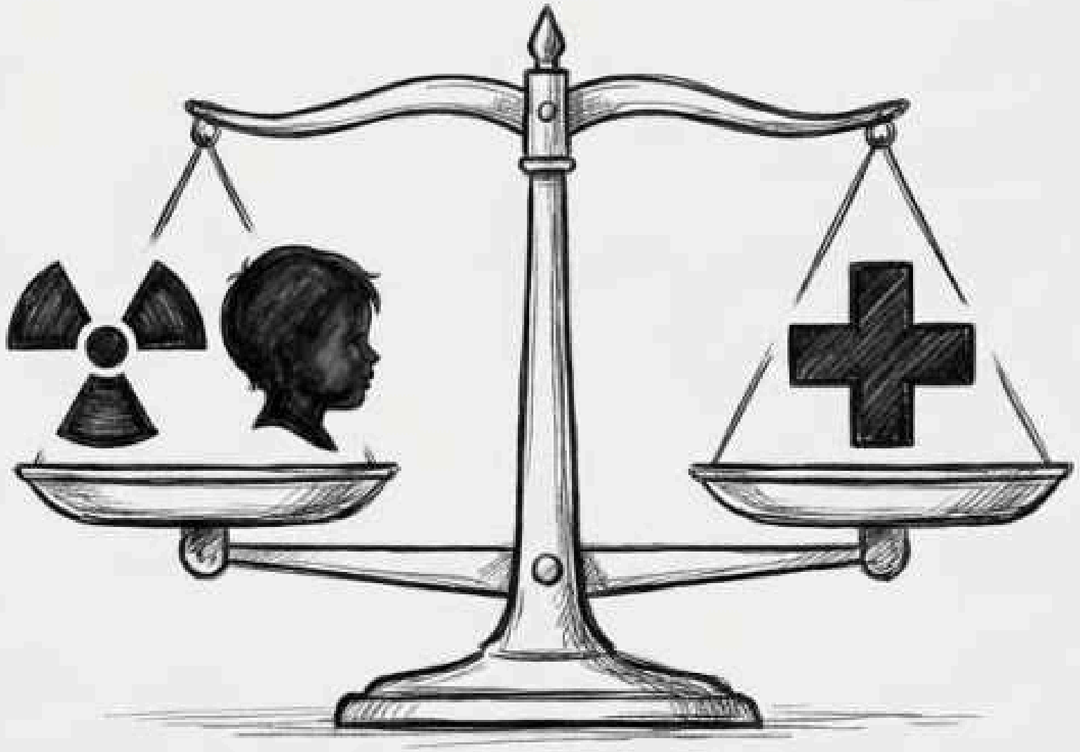


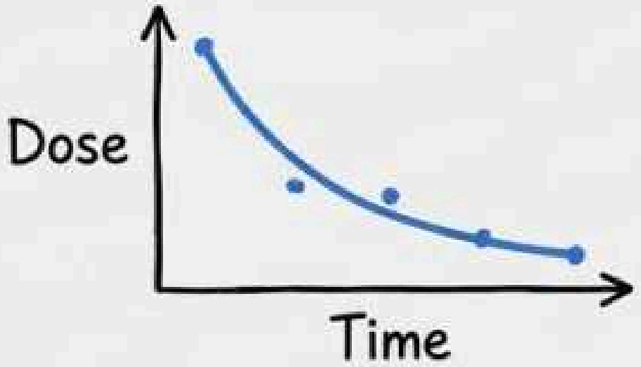
Provides the 3D anatomical map required for targeted radiotherapy.

Gemini Notebook

Radiation Dose: Risk vs. Necessity

¶ 2.8





- ☑ **The Concern:** Delivers higher doses than plain X-rays; studies suggest a small increased cancer risk from childhood scans.
- ☑ **The Mitigation:** Modern scanners and advanced reconstruction software have drastically reduced doses over time.
- ☑ **Paediatric Protocols:** Tuned to use the absolute lowest dose needed to answer the clinical question.
- ☑ **The Ultimate Safeguard:** Clinical justification—simply avoiding scans that are not needed.

Gemini Notebook

Limitations and Trade-offs

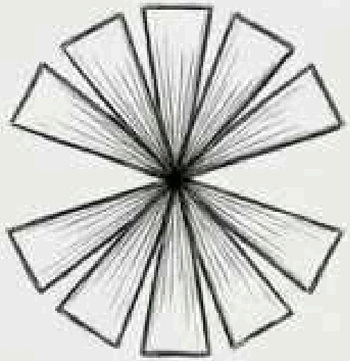
¶ 2.9

Computed Tomography (CT)	Magnetic Resonance Imaging (MRI)
	$Resolution_{soft_tissue}$ MRI > CT
Soft Tissue Detail: CT is inferior to MRI for viewing soft tissues like the brain and muscles.	
Functional Imaging: CT cannot display physiological function well. ✗	✓

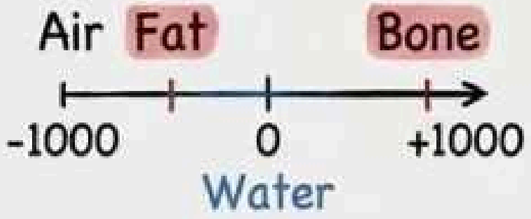
The Medical Cornerstone: Despite these limits, its unmatched combination of speed, anatomical clarity, and widespread availability makes it one of the most important tools in medicine.

Gemini Notebook

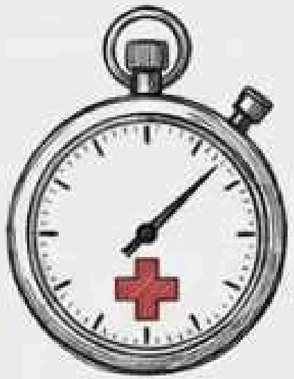
Summary and What's Next



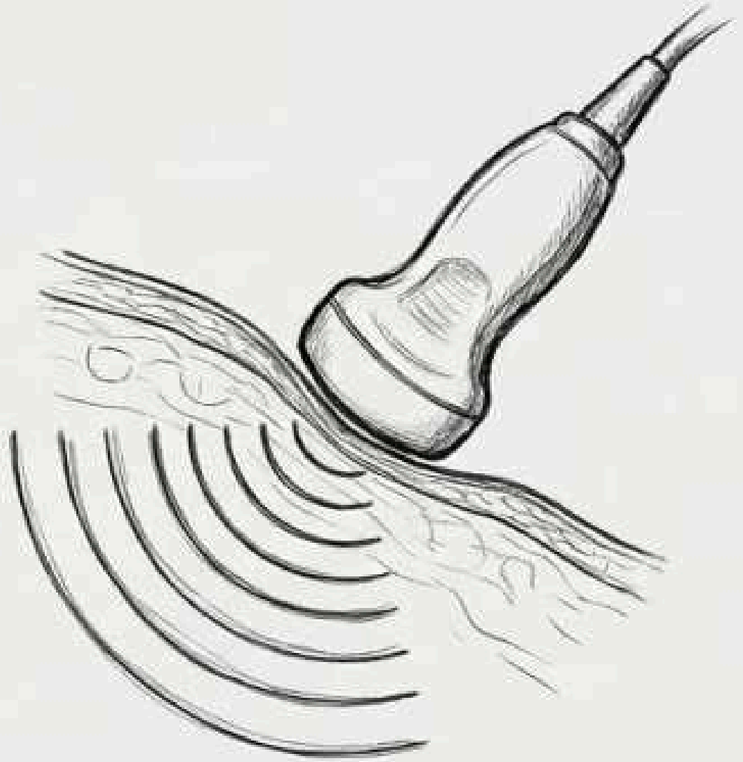
Core Mechanism: CT builds cross-sectional images from X-rays measured at many angles.



Data Translation: Hounsfield units accurately identify specific tissues.



Clinical Value: Unmatched speed secures its role as the premier emergency test.



Up Next (Lecture 3): Transitioning to Ultrasound—a technique requiring absolute zero ionizing radiation.

Gemini Notebook