Medical Education

Computed Tomography (CT-Scan)

See online here

Computerized tomography (CT) is one of the most commonly used imaging modalities as it is widely available, fast, and reliable. CT scans deploy X-rays to obtain cross-sectional images of the body. CT scanners consist of a tube that rotates around the patient and emits an X-ray beam and a detector that receives the beam and converts it to an image with specialized software. Multiple views and the use of contrast allows us to enhance the diagnostic yield of the images produced.

Terminology and Technological Aspects

Two major types of CT scanners exist.

- Helical:
  - Most common
- Conventional, step-and-shoot, axial:
  - Used for high-resolution scanning of the lungs, coronary arteries, and ECG-triggered coronary CT angiography

General components:

- **Rotating X-ray tube** that rotates around the patient
  - Uses ionizing radiation to produce images

- High energy electrodes in the tube emit radiation beams
- Radiation passes through different densities (tissue, fluid, and bone)

- **Radiation detectors** that transverse the patient's body
  - Absorbs the remaining radiation (in the form of pixels) after it has passed through tissues
  - Computer software detects the tomography generated by the detector
  - Produces an image

These computerized images can be digitally manipulated to accentuate different body structures. Body structures are evaluated based on how dense (dark vs. bright) they appear on imaging. Several viewing windows exist including

- Lung window:
  - Used for lung evaluation or intra-abdominal free air detection
- Bone window:
  - Used for bone structure evaluation
- Soft tissue window:
  - Used for solid organ evaluation

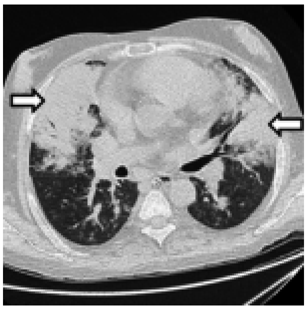


Image: "Imaging panorama in postoperative complications after liver transplantation." Lung window. By B Sureka, K Bansal, S Rajesh, A Mukund, V Pamecha, A Arora. License: CC BY 4.0

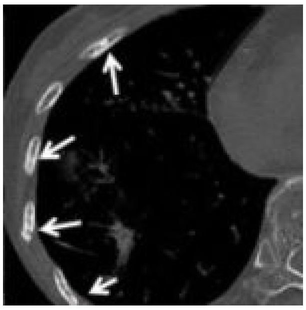


Image: "Rib fracture." Bone window by Nambu A, Onishi H, Aoki S, Koshiishi T, Kuriyama K, Komiyama T, Marino K, Araya M, Saito R, Tominaga L, Maehata Y, Sawada E, Araki T. License: CC BY 2.0 Edited by Lecturio.

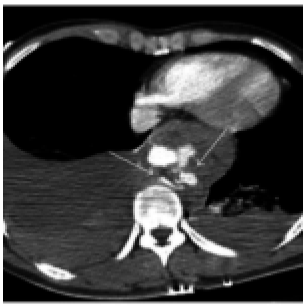
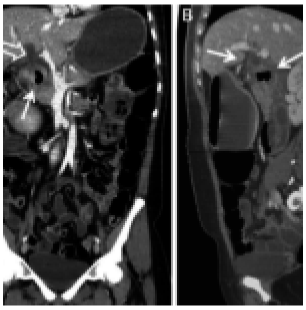


Image: "Stab injury of the thoracic aorta: computed tomography findings." Soft tissue window by Yildiz S, Toprak H, Serter A, Kocakoç E. License: CC BY 3.0

Different viewing panes:



[Image](#): "Lemmel Syndrome Secondary to Duodenal Diverticulitis" by Cureus. License: [CC BY 3.0](#)

- **Axial:**
    - Follows the transverse plane (superior vs. inferior)
- **Sagittal:**
    - Parallel to the sagittal suture (right vs. left)
- **Coronal:**
    - Parallel to the coronal suture (anterior vs. posterior)

<table>
<tr><th>Substance</th><th>Hounsfield Units (HU)</th><td rowspan="6">The darkest(most hypodense)
↕
The brightest
(most hyperdense)</td></tr>
<tr><td>Air</td><td>-1000</td></tr>
<tr><td>Fat</td><td>-100 to -50</td></tr>
<tr><td>Water</td><td>0</td></tr>
<tr><td>Soft Tissue</td><td>+20 to + 300</td></tr>
<tr><td>Bone</td><td>> +700</td></tr>
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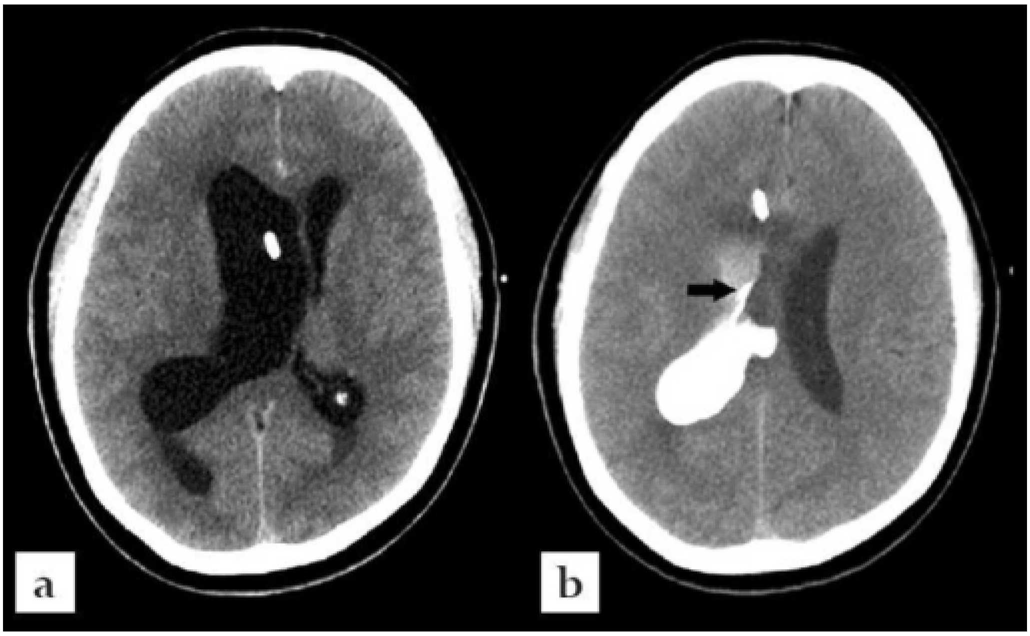

[Image](#): Axial CT images of the brain. Intravenous contrast is used (right) highlighting a right ventricular lesion. by Herrera SR, Chan M, Alaraj AM, Neckrysh S, Lemole MG, Amin-Hanjani S, Slavin KV, Charbel FT. License: [CC BY 2.0](#)

Video Gallery

[Basics of Radiology and Computed Tomography (CT)](#) by Hetal Verma, MD

Considerations when Ordering a CT Scan

Like other imaging modalities, CT scans cause **radiation exposure.**

- Chest and abdominal CT: 10 mSv
- Pelvic CT: 7 mSv
- Head CT: 2 mSv
- For context,
    - Chest X-ray: 0.013 mSv
    - Low-risk of fetal malformation: < 100 mSv
    - Substantial fetal damage: > 500 mSv
- Remember that ionizing radiation is **additive.**
    - Multiple scans should be limited whenever possible.

CT scans can be ordered as either **contrast or non-contrast.**

- **Non-contrast**
    - Used for initial evaluation of
        - Severe head trauma
        - Stroke
        - Intracranial bleeding
- **Contrast**
    - Oral contrast:
        - Either barium (most common) or iodine-based
        - Used for opacification of
            - Ex: Gastrografin is used to evaluate for bowel perforation.
            - GI tract
        - Commonly used for abdominal and pelvic CT scans
    - **Intravenous contrast:**
        - **Iodinated** solution
        - Used for opacification of
            - Vascular structures
            - Solid abdominal and pelvic organs
            - Appears white (“hypodense”)
        - Excreted by **kidneys**
            - **Should be avoided in AKI or CKD**
    - Rectal contrast:
        - Used for suspected penetrating colonic injury

Multiphase CT can identify structures at various intervals after intravenous contrast administration.

- **Non**-contrast phase
    - Prior to contrast injection
- **Vascular or bolus** phase
    - 15–20 seconds post-injection
    - Contrast diffuses into intravasulature
    - Opacifies aorta and its branches
    - Allows differentiation of renal cortex and medulla
- **Redistributions** phase
    - 1–3 minutes post-injection
    - Contrast diffuses from intravascular to extravascular compartment

- Opacifies inferior vena cava, large veins, and solid organ parenchyma
- **Equilibrium** phase
    - 6–10 minutes post-injection
    - Contrast reaches dynamic equilibrium in the intravascular and extravascular compartments
    - Opacifies renal collecting system, ureters, and urinary bladder

Interpretation

The best approach is a **systemic approach.**

- Check the patient's demographics, name, and the date.
- Note the reason for the study.
- Is there a prior image to compare findings?
- Use multiple window levels and scroll through multiple times to ensure all sections are covered.
    - Remember that viewing windows can be changed to optimize viewing of the desired organ system.
- Evaluate one organ at a time.
- Practice makes perfect!

	Radiography	**CT**	**Ultrasound**	**MRI**
Mechanism of acquisition:	Ionizing radiation	Ionizing radiation	Acoustic energy	Ferromagnetic pulses
Relative cost:	Inexpensive	Expensive	Very inexpensive	Very expensive
Portable:	Yes	No	Yes	No
Length of exam:	Seconds	Less than a minute	Seconds	Many minutes to about 1 hour
Contrast:	No	May be needed	No	May be needed

Video Gallery

Multiphase Abdominal CT by Hetal Verma, MD

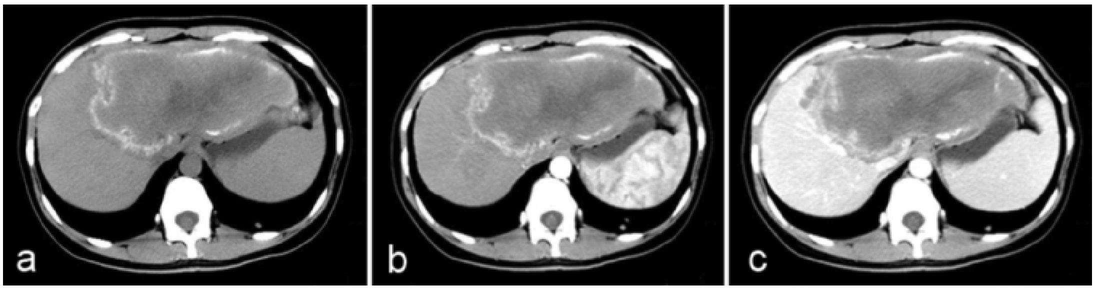

Image: Axial multiphase CT images of the abdomen. (A) Unenhanced image shows an infiltrative tumor-like hepatic mass. (B) Post-contrast arterial phase shows a non-enhancing, hypo-attenuating lesion. (C) Post-contrast portal-venous phase shows a faint enhancement of fibro-inflammatory components surrounding the parasitic pseudocyst. By Wenya Liu, Éric Delabrousse, Oleg Blagosklonov, Jing Wang, Hongchun Zeng, Yi Jiang, Jian Wang, Yongde Qin, Dominique Angèle Vuitton, and Hao Wen. License: CC BY 4.0

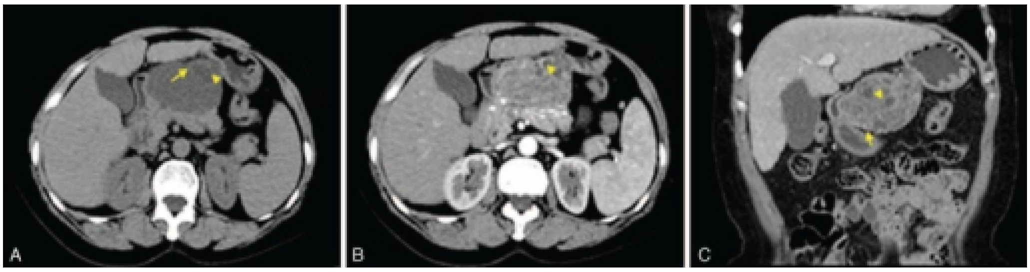

Image: “Axial CT images of the abdomen. Oral contrast is used (A) to better define a cystic mass of the pancreas that is barely visible pre-contrast (B and C). By Pan L, Jian-bo G, Javier PT. License: CC BY 4.0

Indications

	Specifications and examples
Head CT	Non-contrast: • Initial evaluation of ∘ Severe head trauma ∘ Stroke ∘ Intracranial bleeding (appears as a hyperdense lesion) Contrast: • Enhances neoplasms and infections • Used for new-onset headache with focal neurologic deficits
Chest CT	• Evaluation of ∘ Lung parenchymal diseases ■ Interstitial lung disease (lung fibrosis) ∘ Pleura, pulmonary vessels, and lymph nodes ∘ **Pulmonary embolism** (IV contrast required) ∘ Lung cavitations ∘ Hilar lymph nodes ∘ Tumors
Abdomen and pelvis CT	Should be performed with **both** intravenous and oral contrast • Evaluation of abdominal pathologies ∘ Appendicitis, diverticulitis, pancreatitis ∘ Intra-abdominal infections ∘ Urolithiasis (non-contrast) ∘ Blunt abdominal injury ∘ Penetrating abdominal injury ∘ Pneumoperitoneum • Evaluation of visceral malignancies ∘ Staging and tumor identification ∘ Masses within abdominal organs

Video Gallery

Basics of Radiation by Hetal Verma, MD

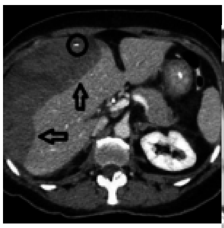
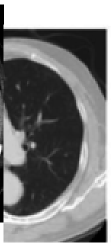
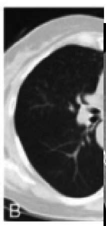
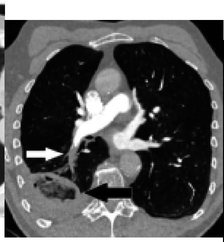
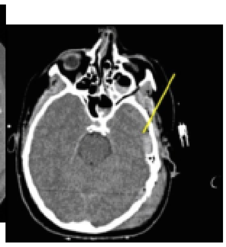

Image: CT scan of the

Image:

Image:

middle abdomen showing a subcapsular hepatic hematoma on the surface of the right lobe of the liver (hypodense area indicated by the arrows) in which is present a source of active bleeding (circle). By Zizzo M, Lanaia A, Barbieri I, Zaghi C, Bonilauri S. License: CC BY 4.0

Typical thin-sliced computed tomography (CT) pictures of central (a) and peripheral (b) types of small cell lung carcinoma (SCLC). Each arrow indicates the primary mass. By Miyauchi E, Motoi N, Ono H, Ninomiya H, Ohyanagi F, Nishio M, Okumura S, Ichinose M, Ishikawa Y. License: CC BY 4.0

Thorax CT of a 74-year-old man with a long-standing pulmonary embolism in the artery in the right lower lobe. It shows the embolism, as well as a pulmonary infarction (white arrow) seen as a reverse halo sign (black arrow). By Mikael Häggström. License: Public Domain

Image: Left temporal bone fracture, pneumocephalus, and left-sided epidural hematoma. By Baugh AD, Baugh RF, Atallah JN, Gaudin D, Williams M. License: CC BY 3.0

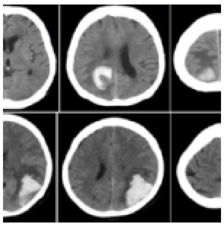

Image: Head multi-slice CT imaging of hemorrhagic stroke patients in two different settings. By Saefudin T, Apriantoro NH, Hidayat ES, Purnamawati S. License: CC BY 3.0

Contradictions

- Prior reactions to contrast agents
    - May manifest as **anaphylaxis**
- Pregnancy
    - Iodinated contrast can cross the placenta
- Patients undergoing treatment for thyroid disease
    - Iodinated contrast will reduce uptake of radioactive iodine making treatment less effective
- Chronic or acutely worsening renal disease
    - Iodinated contrast can cause acute tubular necrosis, so **all** patients should be
        - Well-hydrated prior to contrast administration
        - Use the least possible contrast load

Other Imaging Modalities

Imaging modalities of specific body systems are referenced below:

- Imaging of the Spinal cord and vertebral column
- CNS imaging
- Pulmonary Radiology
- Imaging of the Mediastinum
- Imaging of the liver and biliary tract
- Imaging of the spleen
- Renal imaging
- Imaging of the intestines
- Chest abnormalities
- Bowel abnormalities

Notes