COMPUTED TOMOGRAPHY

Understanding how CT works: its uses, strengths, and weaknesses

What is CT?

Computed tomography (CT) provides us with images (tomograms) showing slices through the body. We can vary the thickness of these slices so that, in effect, we are looking at thin two-dimensional pictures representing a volume of tissue. *Computed axial tomography* (CAT) is a synonym for CT. It refers to the axial plane, the most common plane of CT imaging.

How does CT work?

CT uses X-rays to produce an image. The same basic principles apply to CT as to all other X-ray studies. X-rays are blocked (attenuated) by tissues depending upon their density (atomic number). Air is black on CT and minerals are white.

To obtain a slice, an X-ray source rotates around the body in an arc while an X-ray detection source rotates opposite the source on the opposite side of the body. The computer analyzes the number and density of the transmitted X-rays, calculates the coordinates, and assigns a gray scale to individual picture elements (pixels) that will make the final picture.

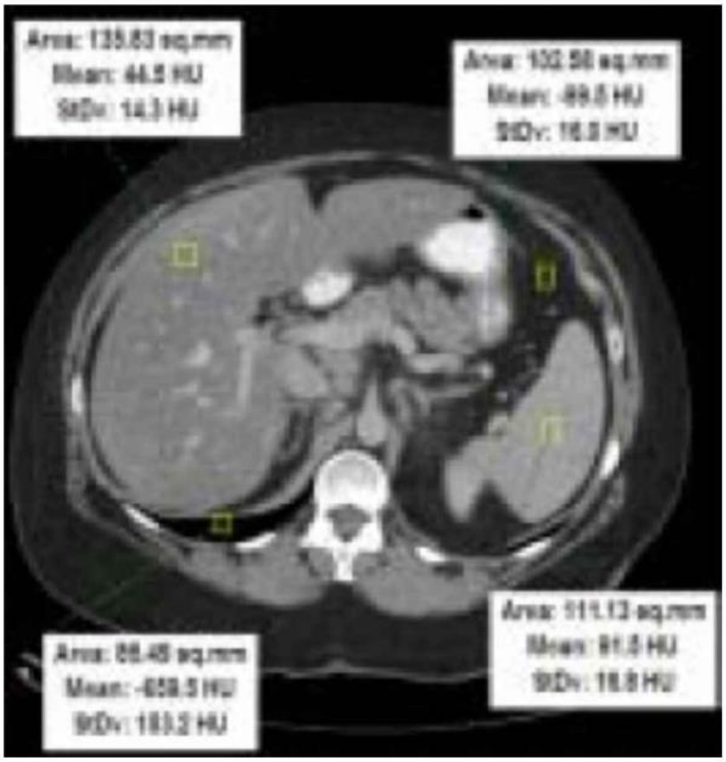
What are Hounsfield units?

Sir Godfrey Hounsfield was instrumental in the development of computed tomography.

His name is used for the numbers associated with the gray scale produced during CT scanning. All CT scanners are programmed such that water appears dark on the image; its attenuation value in Hounsfield units (HU) is 0. From this central point, HU range from calcium at approximately +1,000 HU to air at approximately −1,000 HU.

Common CT-assigned attenuation values:

Air = −1,000 HU or less (black)
Fat = −5 to −50 HU (dark gray)
Water = 0 H U (gray)



CT-assigned attenuation values

Soft tissue = +40 to +80 HU (light gray)
Calcium (stone) = +100 to +400 HU (gray white)
Cortical bone = +1,000 HU (white)

Are there limitations to CT?

CT cannot distinguish soft tissue structures as well as MRI can. For example, the ligaments and menisci of the knee are not different enough in their attenuation values to allow us to delineate them easily or demonstrate specific pathology.

Metal can create a “starburst artifact” that blurs the image. This can happen around the maxillary area and mandible due to dental fillings, as well as around the hip when a prosthesis is present.

CT is limited in the posterior fossa of the brain because of the dense bone in the petrous ridges and the skull base. A “beam-hardening artifact” limits our ability to detect subtle pathology in the brain stem area.

In addition, CT is less sensitive than MRI in the detection of white matter disease of the brain.

What are window settings and how are they used?

Digital technology such as CT, MRI, and digital radiography provides the opportunity for computer-aided manipulation of the image. *Window widths* and *window levels* are used to optimize visualization of specific structures. The window level is the midpoint of the gray scale. The window width is the number of gray shades. If the window level is set to 0 and the window width is set to 1,000, the gray scale is from −500 to +500.

The most obvious example of windowing and leveling technique is chest CT. To evaluate the mediastinum, the window level is set to soft tissue density and the window width is set moderately narrow to allow for optimal contrast. To evaluate the lungs, the window level is set closer to air density and the window width is set relatively wide to allow detailed assessment of the air-bearing lung parenchyma.

CT lung window setting

CT mediastinal window setting

What parts of the body are best studied with CT?

CT can be used from head to toe.

> Head: An excellent screening modality for cranial trauma, suspected intracranial bleeding, or stroke
>
> Paranasal sinuses
>
> Neck
>
> Facial bones
>
> Chest
>
> Abdomen
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> Pelvis
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> Knee: for evaluation of tibial plateau fractures; not good for cartilage or ligament injury evaluation
>
> Hip: specifically for assessment of acetabulum fracture

Calcaneus: fracture

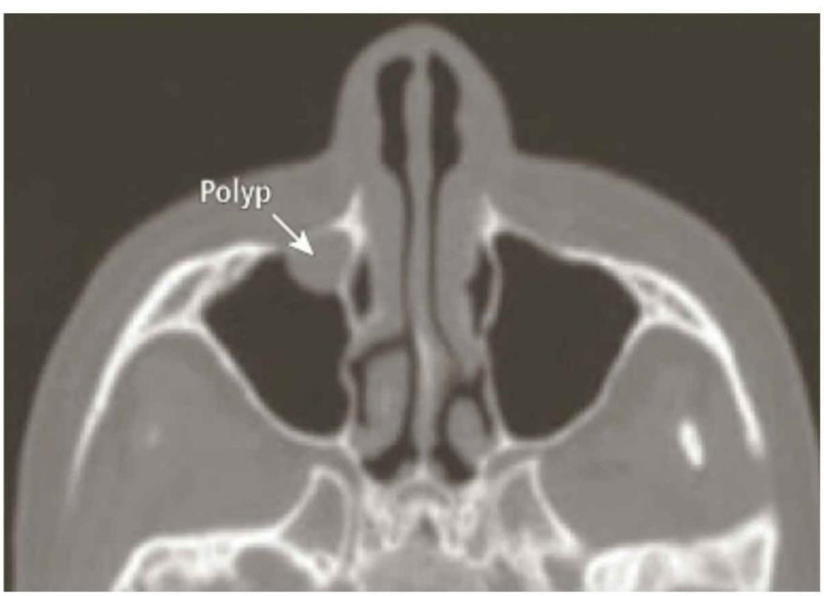
What is contrast CT?

In contrast CT, a fluid containing iodine (mineral density) is injected intravenously. Contrast is routinely employed during chest, abdomen, and pelvis CT. It helps to identify vascular structures so that they may be differentiated from other normal or abnormal structures. Contrast also helps to characterize certain types of pathology, such as infection or vascular malformations. It is not necessary to specify on the order whether you would like contrast to be administered. The exception is head CT, for which you do need to specify contrast. Contrast is indicated if you suspect primary or metastatic cancer, infection (abscess), vascular malformation, or aneurysm.

What are 3D CT and sagittal and coronal reconstruction?

Software provided on CT scanners allows for the conversion of axial images into images in any other plane desired. Three-dimensional images—computer-generated pictures utilizing shading techniques to create the appearance of 3D—are sometimes helpful when evaluating facial bone fractures and acetabulum fractures of the hip prior to reconstruction surgery.

Direct coronal CT of sinuses

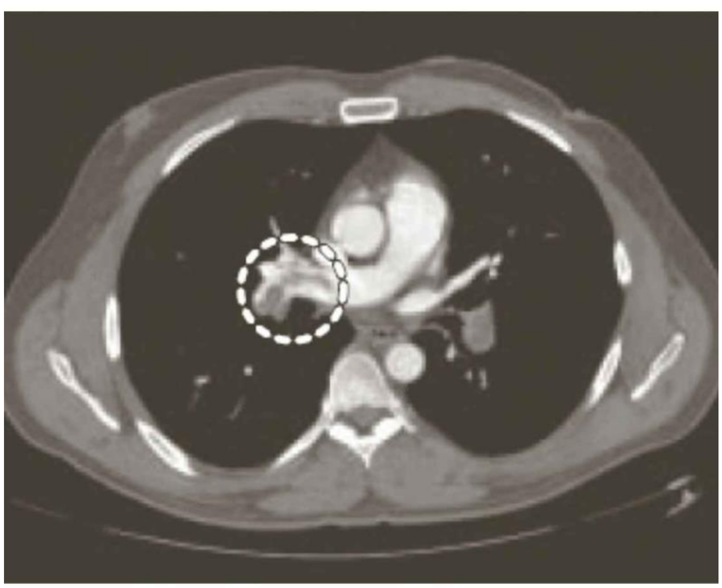


Axial reconstruction of sinuses

What is CTA?

Computed tomography angiography (CTA) is a computer-intensive reconstruction of the vascular structures in the body. Both venous and arterial imaging can be performed using intravenous contrast. lodinated contrast is delivered through an 18-gauge or larger intravenous catheter. A power injector is used to deliver the contrast. The computer can then subtract away any density that does not contain contrast. The vascular system can be seen in excellent detail. CTA is used to detect thrombosis within veins or arteries, stenosis, aneurysms, and vascular malformations. A common indication is for the detection of pulmonary embolism.

CTA: pulmonary arteries



CTA: right pulmonary artery embolus

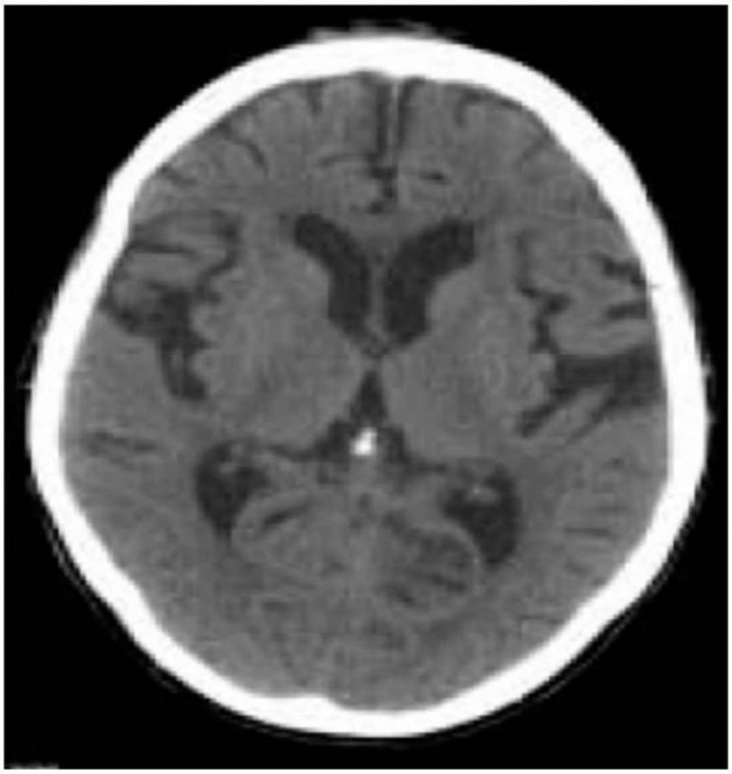
What are the benefits of CT compared to plain radiography?

CT, by "slicing" the anatomy into thin sections, allows us to look inside the body with fewer overlapping shadows than we get with plain radiography. Because every slice does have a certain thickness and therefore volume, it is possible to be fooled when a section contains parts of two different structures, such as when the top of the diaphragm is included on the lowest images of the lungs. This is called partial volume averaging.

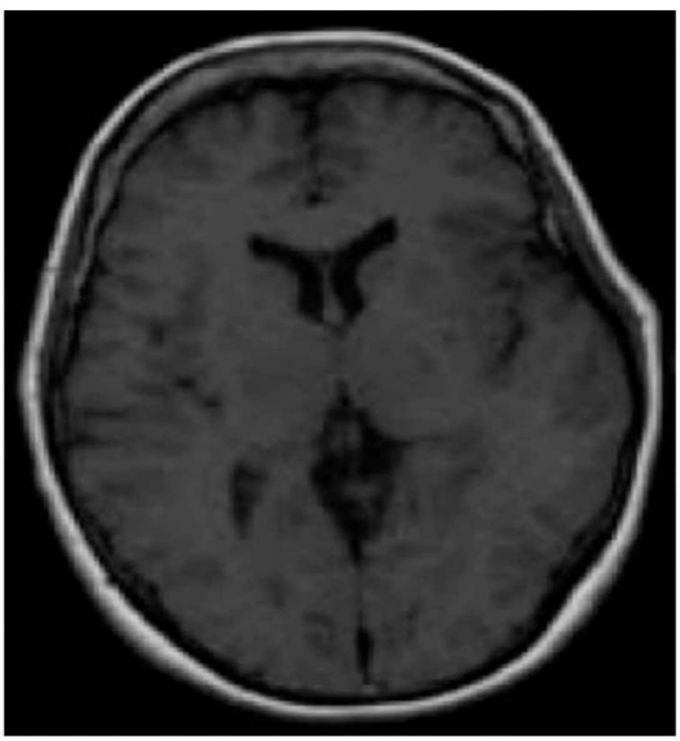
CT also allows us to quantify radiographic density through measuring Hounsfield units. We can therefore be certain about the composition of a structure or mass. Simple cysts have water density. Lipomas have fat density. Blood, as in intracranial hemorrhage, has a specific range of density. CT is preferred to plain X-rays when more anatomic detail is required, such as for the intracranial structures, sinuses, neck, chest, and abdomen, and for assessing the osseous detail of joints. MRI is preferred for looking at soft tissues such as ligaments, cartilage, and disks.

What are the benefits of CT compared to MRI?

CT is an excellent modality for looking for intracranial hemorrhage. It remains the first imaging study when intracranial bleeding is suspected (such as hemorrhagic stroke, subdural, epidural, subarachnoid, or intraparenchymal). CT is excellent for studying cortical bone and is used to assess fracture alignment in the face, cervical spine, acetabulum, knee, and foot (especially the calcaneus). CT continues to be favored in the chest, as well as in the abdomen, although MRI is an excellent modality with many uses in the abdomen. My suggestion is that you consult with the radiologist before ordering an abdominal MRI. CT is generally quicker, less expensive, and more readily available than MRI. It is often better than MRI at assessing cortical bone and for specific density measurements. Please note that there is considerable variation among radiology departments in the type and quality of the imaging equipment; the training, experience, and expertise of the radiologists; and the preferences of the clinical staff. For this reason, expect to find differences in preferred imaging strategies between medical facilities.



Normal CT (note: skull is white adjacent to brain)



Normal T1 MRI (note: skull is black adjacent to brain)

Radiology lectures