20 Basic Principles of CT Imaging

Birendra Kishore Das

CT uses X-rays to generate cross-sectional, two-dimensional images of the body. Images are acquired by rapid rotation of the X-ray tube 360° around the patient. The transmitted radiation is then measured by a ring of sensitive radiation detectors located on the gantry around the patient. The final image is generated from these measurements utilizing the basic principle that the internal structure of the body can be reconstructed from multiple X-ray projections.

The first CT scanner was developed in 1972 by Sir Godfrey Hounsfield. Since then, the modality has become established as an essential radiological technique applicable in a wide range of clinical situations (Fig. 20.1).

How is a CT Image Produced ?

Every acquired CT slice is subdivided into a matrix of up to 1,024 × 1,024 volume elements (voxels). Each voxel has been traversed during the scan by numerous X-ray photons and the intensity of the transmitted radiation measured by detectors. From these intensity readings, the density or attenuation value of the tissue at each point in the slice can be calculated. Specific attenuation values are assigned to each individual voxel. The viewed image is then reconstructed as a corresponding matrix of picture elements (pixels). Each pixel is assigned a numerical value (CT number), which is the average of all the attenuation values contained within the corresponding voxel. This number is compared to the attenuation value of water and displayed on a scale of arbitrary units named Hounsfield units (HU) after Sir Godfrey Hounsfield. In a simple term HU are displayed as various shades of gray to form an image.

Early CT scanners acquired images a single slice at a time (sequential scanning). However, during the 1980s significant advancements in technology heralded the development of slip ring technology, which enabled the X-ray tube to rotate continuously in one direction around the patient. This has contributed to the development of helical or spiral CT.

In spiral CT, the X-ray tube rotates continuously in one direction while the table on which the patient is lying is mechanically moved through the X-ray beam. The transmitted radiation thus takes on the form of a helix or spiral. Instead of acquiring data one slice at a time, information can be acquired as a continuous volume of contiguous slices. This allows larger anatomical regions of the body to be imaged during a single breath hold, thereby reducing the possibility of artifacts caused by patient movement.

B.K. Das, MD, ANM, FAR, FAMS
Director and Chief of Nuclear Medicine,
Utkal Institute of Medical Sciences,
Jaydev Vihar, Bhubaneswar, India
e-mail: bkishoredas@yahoo.com

B.K. Das (ed.), *Positron Emission Tomography: A Guide for Clinicians*,
DOI 10.1007/978-81-322-2098-5_20, © Springer India 2015

Fig. 20.1 A typical modern CT scan machine

The next generation of CT scanners is now commercially available. These multislice or multidetector machines utilize the principles of the helical scanner but incorporate multiple rows of detector rings. They can therefore acquire multiple slices per tube rotation, thereby increasing the area of the patient that can be covered in a given time by the X-ray beam.

Information Obtained from CT Scan

CT scans are used to image a wide variety of body structures and internal organs. Since the 1990s, CT equipment has become more affordable and available. In some diagnoses, CT scans have become the first imaging examination of choice. Because the computerized image is so sharp, focused, and three-dimensional, many tissues can be better differentiated than on standard X-rays. Common CT indications include:

- Sinus studies: The CT scan can show details of a *sinusitis* and bone *fractures*. Physicians may order CT of the sinuses to provide an accurate map for surgery.
- Brain studies: Brain scans can detect hematomas, tumors, and strokes. The introduction of CT scanning, especially spiral CT, has helped reduce the need for more invasive procedures such as cerebral *angiography* and more expensive MRI.
- Body scans: CT scans of the body will often be used to observe abdominal organs, such as the liver, kidneys, adrenal glands, spleen, and lymph nodes, and extremities (Fig. 20.2).
- Aorta scans: CT scans can focus on the thoracic or abdominal aorta to locate aneurysms and other possible aortic diseases.
- Chest scans: CT scans of the chest are useful in distinguishing tumors and in detailing accumulation of fluid in chest infections.

Information for Patient

Pregnant women or those who could possibly be pregnant should not have a CT scan unless the diagnostic benefits outweigh the risks. Pregnant patients should particularly avoid whole body or abdominal scans. If the exam is necessary for obstetrics purposes, technologists are instructed not to repeat films if there are errors. Pregnant patients receiving CT or any X-ray exam away from the abdominal area may be protected by a lead apron. However, most radiation, known as scatter, travels through the body and is not blocked by the apron.

Contrast agents are often used in CT exams and the use of these agents should be discussed

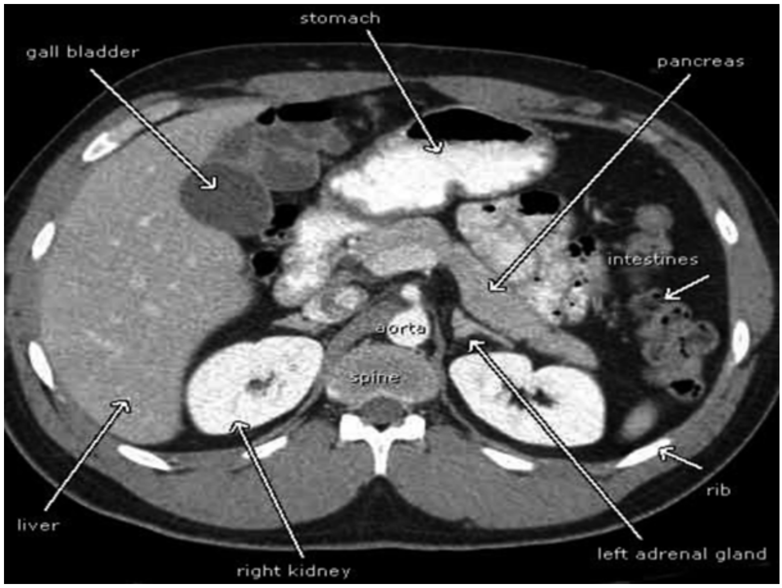

Fig. 20.2 A slice through the abdomen showing different anatomical structures in CT image

with the referring physician prior to the procedure. One of the common contrast agents, iodine, can cause allergic reactions. Patients who are known to be allergic to iodine have to inform the doctor.

Although the equipment looks large and intimidating, it is very sophisticated and fairly comfortable. The patient is asked to lie on a gantry, or narrow table, that slides into the center of the scanner. The scanner looks like a doughnut and is round in the middle, which allows the X-ray beam to rotate around the patient. The scanner section may also be tilted slightly to allow for certain cross-sectional angles.

CT Procedure

The patient will feel the gantry move very slightly as the precise adjustments for each sectional image is made. A technologist watches the procedure from a window and views the images on a computer screen.

It is essential that the patient lie very still during the procedure to prevent motion blurring. In some studies, such as chest CTs, the patient will be asked to hold his or her breath during image capture.

Following the procedure, films of the images are usually printed for the radiologist and referring physician to review. A radiologist can also interpret CT exams on a special computer screen. The procedure time will vary in length depending on the area being imaged. Average study times are from 30 to 60 min. Some patients may be concerned about claustrophobia, but the width of the “doughnut” portion of the scanner is such that many patients can be reassured of openness.

What Additional Information Is Obtained from CT Image ?

While traditional Xrays image organs in two dimensions, with the possibility that organs in the front of the body are superimposed over those in the back, CT scans allow for a more three-dimensional effect. Some have compared CT images to slices in a loaf of bread. Precise sections of the body can be located and imaged as cross-sectional views. The screen before the technologist shows a computer’s analysis of each section detected by the X-ray beam. Thus, various densities of tissue can be easily distinguished.

Spiral CT

Spiral CT, also called helical CT, is a newer version of CT scanning which is continuous in motion and allows for three-dimensional recreation of images. For example, traditional CT allows the technologist to take slices at very small and precise intervals one after the other. Spiral CT allows for a continuous flow of images, without stopping the scanner to move to the next image slice. A major advantage of spiral CT is the ability to reconstruct images anywhere along the length of the study area. The procedure also speeds up the imaging process, meaning less time for the patient to lie still. The ability to image contrast more rapidly after it is injected, when it is at its highest level, is another advantage of spiral CT's high speed.

Radiation Exposure and Risks

Radiation exposure from a CT scan is similar to, though higher than, that of a conventional X-ray. Although this is a risk to pregnant women, the exposure to other adults is minimal and should produce no effects. Although severe contrast reactions are rare, they are a risk of many CT procedures, particularly to those who are allergic to iodine.

Normal Results

Normal findings on a CT exam show bone, the densest tissue, as white areas. Tissues and fat will show as various shades of gray, and fluids will be gray or black. Air will also look black. Intravenous, oral, and rectal contrast appears as white areas. The radiologist can determine if tissues and organs appear normal by the sensitivity of the gray shadows. In CT, the images that can cut through a section of tissue or organ provide three-dimensional viewing for the radiologist and referring physician.

Abnormal Results

Abnormal results may show different characteristics of tissues within organs. Accumulations of blood or other fluids where they do not belong may be detected. Radiologists can differentiate among types of tumors throughout the body by viewing details of their makeup.

PET scanner can be combined with sophisticated CT machine to produce hybrid PET-CT units. The CT component of a PET-CT unit can be used independently as a CT machine to provide diagnostic images. This is used by centers to generate additional revenue.

For Further Reading

1. Goldman LW. Principles of CT: multislice CT. J Nucl Med Technol. 2008;36:57–68.
2. Hendee WR. Cross sectional medical imaging: a history. Radiographics. 1989;9(6):1155–80.
3. Hounsfield GN. Computed medical imaging. Med Phys. 1980;7:277–82.
4. Ledley RS, Wilson JB, Golab T, Rotolo LS. The ACTA scanner: the whole body computerized transaxial tomograph. Comput Biol Med. 1974; 4:145–55.