Approach to Chest Computed Tomography

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KEYWORDS

• Chest CT • Computed tomography • Thoracic imaging

KEY POINTS

- Chest computed tomography (CT) scan protocols are tailored to answer particular clinical questions. Contrast bolus administration, scan range, slice thickness, and CT tube settings are some of the parameters specified for each protocol.
- Postprocessing techniques such as 3-dimensional volume-rendering and maximum intensity projection provide additional ways of visualizing CT data sets and can supplement review of the axial images.
- Competent review of chest CT requires knowledge of normal CT anatomy and a systematic approach to detecting and characterizing thoracic pathology. Appreciation of the major categories of abnormal findings in each anatomic region is essential and provides a starting point for more advanced investigation of the CT appearances of specific diseases.
- Knowledge of a variety of common technical limitations and CT artifacts is essential in avoiding examination misinterpretation and for providing feedback about examination protocol and execution.

INTRODUCTION: DEFINITIONS AND NATURE OF THE PROBLEM

Computed tomography (CT) has become an essential tool in the diagnosis and treatment of a tremendous variety of diseases, with a dramatic increase in utilization since the development of the first CT scanners in the 1970s. Progress in scanner technology and advances in characterization of thoracic diseases have made CT a powerful diagnostic tool. The many contemporary indications for thoracic CT include characterization of pulmonary nodules and lung cancer, pulmonary metastatic disease, diseases of the aorta and pulmonary arteries, infections, postoperative complications, and interstitial lung disease. Electrocardiogram (ECG)-gated cardiac CT has also become a potent tool for evaluation of coronary artery disease and other diseases of the heart.

The complex anatomy of the thorax and the wide range of thoracic diseases with sometimes overlapping CT appearances can make interpretation challenging. The proliferation of CT scan indications and associated scan types can also create confusion in the selection of appropriate examination protocol. The following provides an introduction to the acquisition and review of chest CT, including a review of basic CT techniques and protocols, normal CT anatomy, and an organized approach for reviewing chest CT.

IMAGING TECHNIQUES

Basic Physics of Computed Tomography

CT arose from seminal work performed in the early 1970s by Godfrey Hounsfield, an English electrical engineer, with mathematical foundations pioneered in the 1950s by Allan Cormack; the 2 shared the Nobel Prize in Medicine in 1979 for their work.[1] For CT, the patient is centered on a table within a gantry containing a radiation source. A fan-shaped X-ray beam is directed toward the opposite side of the gantry, where detectors register radiation transmitted through the "slice" of tissue.[2] In modern scanners,

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the source and detectors rotate around the patient, providing data on the attenuation (the loss of photons due to interactions with tissue) of the beam across the range of angles subtended by the rotation. The scanner uses an algorithm to reconstruct the attenuation and position data, rendering a stack of images corresponding to the irradiated tissue. These images portray both the spatial location and the relative "density" or "attenuation" of objects within each CT slice.[3] Different materials have characteristic, reproducible units of CT attenuation, given in Hounsfield units (HU). CT machines are calibrated to assign water an attenuation value of 0, with higher attenuation materials (such as soft tissue and bone) yielding positive HU values, and lower attenuation materials (such as air) corresponding to negative HU values.[4] Typical CT attenuation values are shown in Table 1 and Fig. 1.

Early generation scanners used an *axial* technique. In this technique, the table remains stationary during acquisition of a single slice, after which imaging briefly stops and the table moves as the patient is positioned for the next contiguous slice. Later generations of scanners provided a "helical" or "spiral" technique, with continuous motion of the table and patient while the gantry rotates around the patient. In this technique, a "volumetric" acquisition of the entire thorax can be obtained in one breath-hold, and the resulting images can be reformatted in multiple dimensions.[5] Most CT examinations are now performed with helical technique, with the exception of some high-resolution chest CT (HRCT) studies and prospectively gated cardiac CT examinations.

Scan Protocol

The selection of appropriate CT scan protocol is guided by the clinical question to be answered, in conjunction with patient history. Important considerations include the administration and timing of intravenous contrast, the craniocaudal scan range, and the desired scan slice thickness. A contrast-enhanced examination for a general indication such as evaluation of lung cancer or infection can be performed with a standard rate of injection (typically 2–3 mL/s), with images acquired from the thoracic inlet to the upper abdomen; the adrenal glands are often included in studies performed for cancer staging. Vascular examinations, including evaluation of the aorta and pulmonary arteries, usually require a fast injection (4–5 mL/s) with thin slices acquired over the entire chest.[6] HRCT is usually performed without contrast, with thin (1–2 mm) slices obtained from the lung apices to the lung bases.[7] Cardiac CT is typically performed with a high rate of contrast injection, thin slices, and an ECG-gated acquisition with limited scan range through the heart.

Table 1
Typical computed tomography attenuation values in Hounsfield units

Substance or Organ	Typical HU Value
Air	−1000
Normal lung	−700 to −900
Fat	−100
Water	0
Acute blood	50 to 80
Muscle	50
Intravenous contrast	300
Bone (cortex)	>1000

Data from Huda W, Slone RM. Review of radiologic physics. Baltimore (MD): Williams & Wilkins; 1995; and Seeram E. Computed tomography: physical principles, clinical applications & quality control. Philadelphia: Saunders; 1994.

Patient Preparation, Positioning, and Scan Execution

After consent for intravenous contrast is obtained (if administered), the patient is positioned on the scan table with the body centered within the CT gantry. When possible, the patient's arms are placed above the head for chest CT; this avoids scatter and beam-hardening artifact from the bones and soft tissues of the arm. Next, a "scout topogram" of the patient is obtained (Fig. 2). Performed at very low radiation cost, this planar overview of the patient is used by the technologist to set the superior and inferior boundaries of the scan range to include the anatomy of interest. In addition, most CT scanners use the scout to estimate the patient tissue density at each position along the length of the scan range, increasing the CT tube current in areas of high tissue density (such as the abdomen) and decreasing in regions of low density (such as the lungs) to maintain optimal signal-to-noise ratio while minimizing radiation exposure, a technique known as "tube current modulation."[8]

Optimal timing of a CT intravenous contrast bolus relies on an accurate prediction of the time delay between the beginning of contrast administration and the desired contrast opacification of vessels or organs. For chest CT, an initial "localizer" image, obtained as a single axial CT image prescribed with the help of the scout image, is used to set a circular "region of interest" within the main pulmonary artery (for pulmonary CT angiography) or within the aorta (for arterial and general imaging) (Fig. 3). The scanner can be set to trigger the examination once a threshold contrast