Imaging in chest disease

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Abstract

Chest radiography (CXR) and computed tomography (CT) are among the more commonly needed imaging investigations in patients with lung disease. The CXR is often the first test requested and has the advantage of a low radiation dose. However, the utility of CXR is limited – particularly for diffuse lung diseases – and CT is then generally required. Modern CT scanners can acquire images of the thorax in a single breath-hold and provide exquisite morphological detail, but the added radiation burden should be a major consideration for physicians and radiologists alike.

Keywords Airways disease; chest radiography; computed tomography (CT); consolidation; diffuse parenchymal lung disease; ground-glass opacification; lung cancer

Key points

- Radiological investigation of respiratory diseases is fundamental to clinical management
- Plain chest X-ray remains an important test, having the advantages of technical simplicity and a low radiation dose. However, in contrast to computed tomography (CT) it is limited by anatomical superimposition and poor contrast resolution
- In diffuse parenchymal lung disease and airways pathology, high-resolution CT (HRCT) is a vital component of diagnostic evaluation – in experienced hands, HRCT increases observer confidence and accuracy
- CT and ^{18}FDG-PET imaging have a vital role in the diagnosis and staging of lung cancer

Introduction

Imaging tests in patients with suspected or established lung disease are regularly requested by clinicians. In routine practice, chest radiography (CXR) and computed tomography (CT) are the common investigations. However, in specific circumstances, other tests (e.g. thoracic ultrasonography (US) to investigate a pleural effusion or ^{18}fluorodeoxyglucose positron emission tomography (^{18}FDG-PET) for patients with lung cancer) may be indicated. In this review, the basic principles of imaging tests are discussed and the advantages and limitations of each considered. Common terms that appear in radiology reports are discussed, followed by a review of radiological features in some common and some less familiar pulmonary diseases.

Imaging tests commonly requested in clinical medicine

Chest radiography

Despite its acknowledged limitations, the CXR has been a mainstay of investigation in patients with respiratory disease. In most institutions, digital technology with soft-copy review on monitors using picture archiving and communications systems is the norm. Because of the relatively low radiation burden, the CXR is a valuable test not only for confirming the presence of lung disease, but also in follow-up (Table 1).

However, interpretation of CXRs can be problematic. Anatomical superimposition (because of the two-dimensional format) makes the characterization of radiological patterns difficult. Another issue is the limited contrast resolution (i.e. the ability to distinguish between tissues of differing physical density). Accordingly, in specific clinical scenarios (most notably diffuse parenchymal lung disease (DPLD)), the confidence and accuracy of a CXR diagnosis are too low.[1]

The standard CXR projection is the 'postero-anterior' (PA) projection, in which the radiographic film cassette is in front of the patient and the X-ray source mounted behind. The PA projection minimizes magnification of the cardiac and mediastinal structures caused by the divergent X-ray beam. The antero-posterior (AP) projection, where the patient faces the X-ray source and the radiographic cassette is against their back, is generally reserved for immobile or critically ill patients; its drawback is that image quality can be substandard.

Indications for chest X-ray (CXR)

Clinical settings in which CXR may be of value

- Investigation of patients with symptoms or signs of respiratory disease
- Initial evaluation in patients with suspected lung cancer
- As part of 'baseline' tests in other chronic but non-malignant lung disease (e.g. sarcoidosis, hypersensitivity pneumonitis, bronchiectasis)
- As a 'triage' tool in diagnostic algorithms for patients with suspected acute pulmonary embolism (PE)
- Initial screening for patients with systemic disorders (e.g. rheumatoid arthritis, systemic sclerosis) in which lung disease occurs and contributes significantly to morbidity and mortality
- Follow-up (e.g. after treatment or a period of observation) in patients with established acute or chronic lung disease

Clinical settings in which CXR has less impact

- Accurate morphological characterization and diagnosis of diffuse interstitial lung disease
- Accurate diagnosis of airways disease (e.g. bronchiectasis, obliterative bronchiolitis)
- Diagnosis of acute PE
- Staging of lung cancer and other extrathoracic malignancies

Table 1

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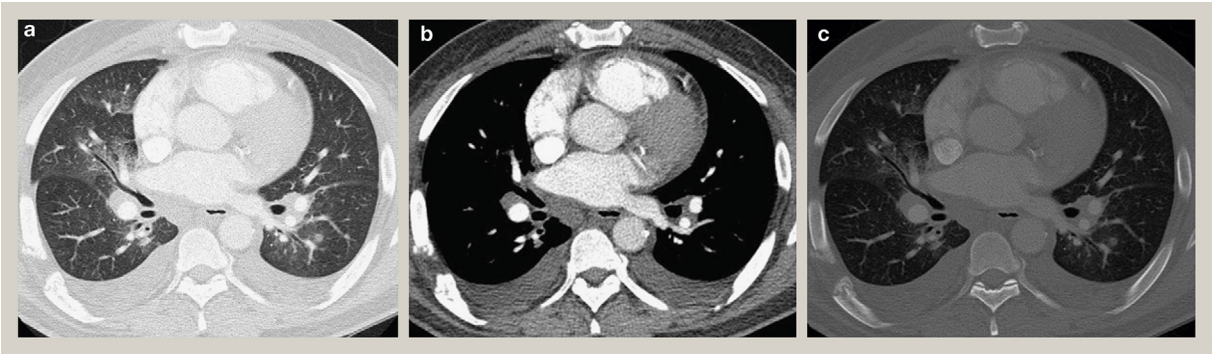

Figure 1 Three CT images from a single acquisition, photographed at identical anatomical levels but displayed on three different window settings: (**a**) lung, (**b**) soft tissue, (**c**) bone.

Other radiographic projections (e.g. the lateral, lateral 'shoot-through' and lordotic views) are requested less frequently, largely because of the wider availability of and access to CT.

Computed tomography

The key components of all CT machines (including modern multi-detector-row CT) are the X-ray tube and detector, computer hardware to reconstruct the image and a sliding table; in the newest generation of multidetector scanners, this moves continuously during scanning.

The essence of CT imaging is differential attenuation as the X-ray beam passes through tissues of varying physical density. The X-ray source and detectors rotate around the patient, and the transmitted X-ray energy, from all projections, is captured by the detector array.[2] The final image comprises a matrix of picture elements (pixels). Each pixel is assigned a numerical value (ranging from −1000 through 0 to +1000 Hounsfield units (HU)) proportional to the attenuation in that specific volume (voxel) of tissue.

Based on these Hounsfield values, each pixel is assigned a 'colour' or grey-scale value reflecting the tissue: bone is highly attenuating and has a grey-scale value that is represented as white, whereas air is represented by pixels that are nearly black. All other tissues and fluids have intermediate grey-scale values. One of the advantages of CT is that the observer can, by choosing the appropriate 'window' settings, use the digitized data to focus on different tissues (Figure 1). Typical settings for analysing the lung parenchyma are a window centred at around −550 HU with a width of 1500 HU.

High-resolution CT (HRCT; Table 2) represents an important advance in lung imaging. Narrow-beam collimation, the use of a dedicated (mathematical) image reconstruction algorithm and a small field of view are the features of HRCT imaging. However, a fourth element of HRCT, sometimes forgotten in the era of multi-detector CT (MDCT), is the gap (typically 10–20 mm) between image slices. The logic is that, in diffuse lung disease, the whole lung does not need to be 'sampled', which lowers the radiation dose significantly.[3] The thin collimation inherent in HRCT scanning reduces partial volume averaging and, together with the high-spatial-frequency reconstruction, gives HRCT images of the lung their characteristic 'sharp' appearance (Figure 2).

The development of spiral or helical CT scanning was a significant advance. This has a greater acquisition speed and consequent reduction of misregistration artefacts caused by inconsistent breath-holds between scanning segments.[4,5] The addition of further detectors in MDCT machines led to significant reductions in acquisition times: modern MDCT machines can acquire images of the whole chest during a single breath-hold. In addition, the very thin collimation of images on MDCT machines generates lung images of exceptional detail. MDCT images can be reconstructed in any plane desired, thereby matching the capabilities that were previously the domain of magnetic resonance imaging (MRI).

^{18}Fluorodeoxyglucose positron emission tomography

^{18}FDG-PET has become particularly important in the field of cancer diagnosis and follow-up. Clinical PET is based on the principle that metabolically active tissues need glucose. For scanning for most clinical indications, glucose is coupled with a radioactive positron-emitting nuclide of fluorine (^{18}F), producing ^{18}fluorodeoxyglucose. A positron-emitting isotope is one that is unstable by being neutron deficient. The instability causes the transmutation of a proton into a neutron, releasing a positron and a neutrino. The reaction between the positron and an electron creates two γ-ray photons that travel at 180° to each other, and these that are captured by the PET detectors. Thus, PET scanners build a 'map' of metabolically active tissues.

One drawback of PET images is their limited spatial resolution. This has been overcome in 'hybrid' PET-CT machines that fuse (i.e. co-register) the superior anatomical detail of CT with the functional information provided by ^{18}FDG-PET.

Indications for high-resolution computed tomography

- Patients in whom diffuse parenchymal lung disease (DPLD) is strongly suspected but there is a normal chest X-ray (CXR)
- To establish a histospecific diagnosis of a DPLD when there is an abnormal CXR
- To clarify the morphological basis of sometimes complex lung functional impairment profiles (e.g. emphysema coexisting with lung fibrosis)
- For 'staging' the extent and severity of lung disease (e.g. before commencing treatment or in clinical trials or research)
- For the diagnosis and follow-up of patients with airways disease (e.g. bronchiectasis, obliterative bronchiolitis)

Table 2