HOW TO REPORT A HRCT

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High-resolution computed tomography (HRCT) imaging has a central role in the diagnosis of interstitial lung diseases. HRCT scans are an integral part of the evaluation of patients with diffuse lung diseases, allowing greater agreement among radiologists regarding to observed patterns. In addition to being used for the diagnosis of pulmonary lesions, CT scans also are determining prognosis and monitoring the progression of lesions and treatment response.
The key technical requirements for ‘best practice’ HRCT are volumetric acquisition and thin-section reconstruction. This is now generally preferred to standard HRCT imaging (eg, 1mm scans with 10mm interval) because it improves both, the identification of small findings (e.g. lung nodules), and the characterization of patterns. Importantly, volumetric HRCT acquisition allows better differentiation between honeycombing and traction bronchiectasis which may be proved crucial to diagnose or rule out IPF. Volumetric (rather than interspaced acquisition) imaging data provides multiplanar reconstructions (coronal and sagittal) of the entire lung improving the evaluation of abnormalities distribution and the extent of disease. The major drawback of the volumetric technique is the high radiation dose exposure. Such a concern should be taken into account particularly when examining young patients.
HRCT scans are usually obtained with the patient in supine position. However, when limited (not extensive) ILD is suspected, prone imaging could be of use. Frequent finding of increasing in attenuation of the dependent lung (in the supine position, the postero-basal segments of the lower lobes) may mimic subtle interstitial abnormalities. However, this can be generally recognized as a normal finding if CT sections obtained in the prone position confirm its reversibility.
Anatomy. – The acinus is a structural and functional unit of the lung distal to a terminal bronchiole and is supplied by first-order respiratory bronchioles; it contains alveolar ducts and alveoli. It is a unit in which all airways participate in gas exchange and is approximately 6–10 mm in diameter. One secondary pulmonary lobule contains between three and 25 acini.

Radiographs and CT. – Individual normal acini are not visible, but acinar arteries can occasionally be identified on thin-section CT scans. Accumulation of pathologic material in acini may be seen as poorly defined nodular opacities on chest radiographs and thin-section CT images.
Anatomy. – The lobule is the smallest unit of lung surrounded by connective-tissue septa. The lobule is also referred to as the secondary pulmonary lobule; it contains a variable number of acini, is irregularly polyhedral in shape, and varies in size from 1.0 to 2.5 cm in diameter. The centrilobular structures, or core structures, include bronchioles and their accompanying pulmonary arterioles and lymphatic vessels.

CT. – On thin-section CT scans, the three basic components of the lobule – the interlobular septa and septal structures, the central lobular region (centrilobular structures), and the lobular parenchyma – can be identified.

CT. – The pulmonary artery and its immediate branches are visible in the center of a secondary lobule on thin-section CT scans, particularly if thickened (e.g., by pulmonary edema). These arteries measure approximately 0.5–1.0 mm in diameter. However, the normal bronchiole in the center of the secondary pulmonary lobule cannot be seen on thin-section CT scans because of the thinness of its wall (approximately 0.15 mm).
# Visibility of normal structures on HRCT

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<th>Normal lung structures visible on HRCT</th>
<th>Normal lung structures not visible on HRCT</th>
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<td>Bronchi (down to eighth generation)</td>
<td>Lymphatic vessels</td>
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Throughout the lung the bronchi and pulmonary arteries run and branch together. Both the bronchi and pulmonary arteries travel radially.

The bronchovascular bundle is surrounded by a connective tissue sheath from its origin at the hilum to the respiratory bronchioles in the lung periphery. The concept of separate, but connected, components making up the lung interstitium, is important to the understanding of HRCT findings in interstitial lung disease: the *peripheral interstitium* (subpleural interstitium) surrounds the surface of the lung beneath the visceral pleura and penetrates the lung to surround the pulmonary lobules (*paraseptal interstitium*). Within the lobules, a finer network of *septal* connective tissue fibers (*intralobular interstitium*) support the alveoli. The *axial* fibers form a sheath around the bronchovascular bundles (*peribronchovascular interstitium*) which extends from the pulmonary hilum to the lung periphery. The connective tissue stroma of these separate components is in continuity and thus forms a fibrous skeleton for the lungs and a potential place for diffuse infiltrative disease.

Any thickening of the connective tissue interstitium will result in apparent bronchial wall thickening. The size of the smallest subsegmental bronchi visible on HRCT is determined by the thickness of the bronchial wall rather than their diameter.
Inexact terms, often used for the description of radiographs, have mostly been replaced by precise morphologic terms derived from an understanding of normal HRCT anatomy. Over the years there has been convergence on the majority of terms used in HRCT. Some of the most frequently encountered terms in the HRCT lexicon are included in the glossary of terms for thoracic imaging by the Fleischner Society.


Members of the Fleischner Society compiled a glossary of terms for thoracic imaging that replaces previous glossaries published in 1984 and 1996 for thoracic radiography and computed tomography (CT), respectively. The need to update the previous versions came from the recognition that new words have emerged, others have become obsolete, and the meaning of some terms has changed.
Diffuse abnormalities of the lung parenchyma on HRCT can be broadly categorized into one of the following four patterns:

1. Reticular and short linear opacities;
2. Nodular opacities;
3. Increased lung opacity (ground-glass opacity or consolidation);
4. Cystic airspaces and areas of decreased lung density.

Although these HRCT patterns mostly correspond to recognizable patterns on chest radiography, they are seen with much greater clarity on the cross-sectional images of HRCT and the precise distribution of disease is more readily appreciated.
Reticular pattern

- A reticular pattern on HRCT almost always represents interstitial disease. The term is purely descriptive (reticulum = network) and there are several morphologic variations to this basic pattern, ranging from generalized thickening of the interlobular septa to honeycomb lung destruction.

Morphologic subtypes of reticular pattern

- Thickened interlobular or intralobular septa
- Perilobular thickening
- Miscellaneous causes of intersecting linear opacities
- Honeycomb (fibrotic) destruction

- A reticular pattern caused by thickening of interlobular septa is a frequent finding in many interstitial lung diseases. Numerous thickened interlobular septa indicate an extensive interstitial abnormality. Causes of interlobular septal thickening include infiltration with fibrosis, abnormal cells, and fluid (for example, interstitial fibrosis, lymphangitis carcinomatosa and pulmonary edema, ).

- Thickened interlobular septa may appear smooth or irregular on HRCT.
Diseases in which thickened interlobular septa are identifiable on HRCT

- Dominant feature
  - Lymphangitis carcinomatosa
  - Hydrostatic pulmonary edema
  - Venoocclusive disease
  - Pulmonary vein atresia
  - Alveolar proteinosis
  - Lipoid pneumonia
  - Leukemia or lymphoma infiltration
  - Septal amyloidosis
  - Diffuse pulmonary lymphangiomatosis
  - Kaposi sarcoma
  - Congenital lymphangiectasia
  - Acute eosinophilic pneumonia
  - Rare storage diseases, including Erdheim–Chester disease and Niemann–Pick disease
  - Congenital surfactant deficiencies
  - Sarcoidosis
Diagram of HRCT appearances of interstitial infiltration in lymphangitis carcinomatosa.

Schematic representation of HRCT appearances in idiopathic pulmonary fibrosis, distortion and dilatation of the bronchi, ground-glass opacification (bottom left).
Diseases in which thickened interlobular septa are identifiable on HRCT

Typical HRCT appearances of usual interstitial pneumonia in a patient with idiopathic pulmonary fibrosis. Subpleural reticular pattern consists of some destroyed lung (honeycomb).

Patient with reticular pattern there are small cystic airspaces.
Reticular pattern
Nodular pattern

- The distribution of nodules shown on HRCT is the most important factor in making an correct diagnosis in this pattern. In most cases small nodules can be placed into one of three categories: perilymphatic, centrilobular or random distribution.

- **Perilymphatic distribution**
  In patients with a perilymphatic distribution, nodules are seen in relation to pleural surfaces, interlobular septa and the peribronchovascular interstitium. Nodules are almost always visible in a subpleural location, particularly in relation to the fissures.

- **Centrilobular distribution**
  In certain diseases, nodules are limited to the centrilobular region. Centrilobular nodules spare the pleural surfaces. The most peripheral nodules are centered 5-10mm from fissures or the pleural surface.

- **Random distribution**
  Nodules are randomly distributed relative to structures of the lung and secondary lobule. Nodules can usually be seen to involve the pleural surfaces and fissures.
Algorithm for nodular pattern

- The algorithm to distinguish perilymphatic, random and centrilobular nodules is the following:
  - Look for the presence of pleural nodules. These are often easiest to see along the fissures. If pleural nodules are absent or few in number, the distribution is likely centrilobular.
  - If pleural nodules are visible, the pattern is either random (miliary) or perilymphatic.
  - If there are pleural nodules and also nodules along the central bronchovascular interstitium and along interlobular septa, you are dealing with a perilymphatic distribution.
  - If the nodules are diffuse and uniformly distributed, it is likely a random distribution.
Perilymphatic distribution
Perilymphatic nodules are most commonly seen in sarcoidosis. They also occur in silicosis, coal-worker's pneumoconiosis and lymphangitic spread of carcinoma. Notice the overlap in differential diagnosis of perilymphatic nodules and the nodular septal thickening in the reticular pattern. Sometimes the term reticulonodular is used.

Centrilobular distribution
Centrilobular nodules are seen in:
- Hypersensitivity pneumonitis
- Respiratory bronchiolitis in smokers
- Infectious airways diseases (endobronchial spread of tuberculosis or nontuberculous mycobacteria, bronchopneumonia)
- Uncommon in bronchioalveolar carcinoma, pulmonary edema, vasculitis

In many cases centrilobular nodules are of ground glass density and ill defined. They are called acinair nodules.
Increased lung opacity is called ground-glass-opacity (GGO) if there is a hazy increase in lung opacity without obscuration of underlying vessels and is called consolidation if the increase in lung opacity obscures the vessels.

In consolidation, there is exclusively air left intrabronchial. This is called the 'air bronchogram'.

Ground-glass opacity (GGO) represents:

- Filling of the alveolar spaces with pus, edema, hemorrhage, inflammation or tumor cells.
- Thus ground glass in itself is very unspecific.
Increased lung opacity (ground-glass opacity or consolidation)

Broncho-alveolar cell carcinoma with ground-glass opacity and consolidation
The fourth pattern includes abnormalities that result in decreased lung attenuation or air-filled lesions. These include:

- Emphysema
- Lung cysts (LAM, LIP, Langerhans cell histiocytosis)
- Bronchiectasis
- Honeycombing
- Most diseases with a low attenuation pattern can be readily distinguished on the basis of HRCT findings.

**Emphysema**

- Emphysema typically presents as areas of low attenuation without visible walls as a result of parenchymal destruction.
- **Centrilobular emphysema**
- **Panlobular emphysema**
- **Paraseptal emphysema**
Cystic airspaces and areas of decreased lung density.

**Cystic lung diseases**
- Lymphangioleiomyomatosis
- Langerhans cell histiocytosis
- Lymphocytic interstitial pneumonia
- Pneumatoceles (PCP)
- Honeycombing

**Bronchiectasis**
- Prior infection (focal bronchiectasis)
- Cystic fibrosis
- Asthma (ABPA)
- Immune deficiency

**Honeycombing**
- UIP or Interstitial fibrosis
  - IPF
  - RA, scleroderma
  - Drug reaction
  - Asbestosis
  - End stage hypersensitivity pneumonitis
- End stage sarcoidosis
### Differential diagnosis of interstitial lung diseases

#### Reticular pattern

- **Lymphangitic carcinomatosis:** irregular septal thickening, usually focal or unilateral 50% adenopathy', known carcinoma.
- **Cardiogenic pulmonary edema:** incidental finding in HRCT, smooth septal thickening with basal predominance (Kerley B lines), ground-glass opacity with a gravitational and perihilar distribution, thickening of the peribronchovascular interstitium (peribronchial cuffing).
- **Lymphangitic carcinomatosis with hilar adenopathy.**
- **Alveolar proteinosis:** ground glass attenuation with septal thickening (crazy paving).
- **Cardiogenic pulmonary edema.**

#### Nodular pattern

- **Hypersensitivity pneumonitis:** ill defined centrilobular nodules.
- **Miliary TB:** random nodules.
- **Sarcoidosis:** nodules with perilymphatic distribution, along fissures, adenopathy.
- **Hypersensitivity pneumonitis:** centrilobular nodules, notice sparing of the area next to pleura and fissure.
- **Sarcoidosis:** nodules with perilymphatic distribution, along fissures, adenopathy.
- **Respiratory bronchiolitis in infection.**
Increased lung density

- Chronic eosinophilic pneumonia with peripheral areas of ground glass opacity.
- Sarcoid end-stage with massive fibrosis in upper lobes presenting as areas of consolidation. Notice lymphadenopathy.
- Chronic eosinophilic pneumonia with peripheral areas of consolidation.
- Broncho-alveolar cell carcinoma with both areas of ground glass opacity and consolidation.
- Non specific interstitial pneumonitis (NSIP): ground glass with traction bronchiectasis, no honeycombing.
- Cryptogenic organizing pneumonia (COP).
- Sarcoidosis end-stage: consolidation as a result of massive fibrosis perihilar and in upper lobes.

Decreased lung density

- Lymphangiomatomyomatosis (LAM): uniform cysts in woman of child-bearing age; no history of smoking; adenopathy and pleural effusion; sometimes pneumothorax.
- LCH: multiple round and bizarre shaped cysts; smoking history.
- Honeycombing
- Centrilobular emphysema: low attenuation areas without walls.
- Centrilobular emphysema: low attenuation areas without walls. Notice the centrilobular artery in the center.
- Langerhans cell histiocytosis (LCH): multiple thick walled cysts; smoking history.
When radiologists are confronted with a diffuse lung disease, the identification of honeycombing or peribronchovascular thickening allows the working diagnosis to be accurate in over 90% of the images analyzed. In cases in which there are lung cysts, accuracy ranges from 80 to 89%.

The identification of these patterns and their association with specific diseases allow definitive diagnosis without the need for biopsy, principally when there is a correlation between the patterns observed and the clinical data. This is true in a number of situations, principally in usual interstitial pneumonia. In approximately 50% of cases, HRCT findings suffice for the differentiation between usual interstitial pneumonia, nonspecific interstitial pneumonia and the chronic form of hypersensitivity pneumonia. In addition, HRCT is useful for the diagnosis of other diseases, such as lymphangitic carcinomatosis, silicosis, sarcoidosis and the subacute form of hypersensitivity pneumonia, as well as pulmonary alveolar proteinosis.

The overall accuracy of the clinical diagnosis of idiopathic pulmonary fibrosis in specialized centers is good (87.2%).
Undoubtedly, HRCT scans are a valuable tool for the diagnosis of patients with diffuse lung diseases. However, we must consider the limitations of HRCT for this purpose and, above all, the method should be based on the clinical condition of the patient.

Radiologists play a key role in this diagnostic process and in patient follow-up. They should be aware of their limitations, which are related to individual experience and to the method itself.

Radiologist should be familiar with all 4 type of patterns that occur in ILD and their distribution.

The limitations of the method include nonspecific lesion patterns (e.g., ground-glass attenuation), a large number of diseases with similar findings and the fact that one disease might present with different patterns or have an uncharacteristic presentation.

Accuracy in the diagnosis of ILD can range from 50-90% without biopsy depending on specialized centers and experienced radiologists.
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