Submacroscopic lung anatomy and early pathologic changes of various pulmonary diseases: Recognition with HRCT

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- Submacroscopic anatomy of normal lung parenchyma
- Demonstration of normal lung structures with HRCT
- Early changes of various lung diseases and their recognition with HRCT

Anatomy of lung parenchyma necessary for HRCT

Transaxial, tomographic image

Tomographic anatomy

HRCT
Fine structures of the lung

Submacroscopic anatomy of all structures of normal lung

Features of tomographic anatomy of human lung

- Relationship of Br, PA and PV
  - Br + PA (BVB)
  - PV
- Branching of Br and PA
  - main branches
  - side branches
- Alternate location
  - BVB
  - PV
- Secondary pulmonary lobule
  Lung unit supplied by several bronchioles branching at short intervals

Secondary pulmonary lobule

- about 1 cm in size
- supplied by several TBs
- core structures:
  Bronchiole, PA
- border structures:
  PV, Pleura, Interlobular septum (incomplete)
Pulmonary acinus

Complicated branching of high-order RB and alveolar duct and sac

Anatomy of pulmonary artery - alveolar capillaries

Microangiography

PAgraphy in autopsied lung specimen

Main branches
Small side branches

Anatomy of pulmonary veins

PVgraphy in autopsied lung specimen

Large lobular border PV
Small intralobular PV

Pulmonary interstitium

Interstitium including alveolar capillaries
- in alveolar wall → alveolar wall interstitium

Interstitium including bronchial a. & v., lymphatic vessels
- around bronchi and PA → peribronchovascular (axial) interstitium
- around PV
- in the interlobular septum → peripheral interstitium
- in the pleura

Peribronchovascular interstitium

Br : Bronchus
PA: Pulmonary artery

Bronchial vessels (B)
Lymphatic vessels (L)

Peribronchovascular and peripheral interstitium

Hilum
Respiratory bronchiole

PA: Pulmonary artery
L: Lymphatic vessels
Normal interlobular septum

Subpleural area Central area

Bronchial circulation

BAgraphy in autopsied lung

Bronchial circulation and pulmonary circulation

- Peribronchial cuffing
- Hilar haze in pulmonary venous hypertension

Pulmonary lymphatics

Lymphography in autopsied lung

Schema of pulmonary lymphatic vessels

Secondary lobule

Hilum

Demonstration of normal lung structures with HRCT

Visibility of normal pulmonary vessels
Visibility of normal bronchi
Visibility of normal interlobular septa
Smallest visible vessel on HRCT
Lung specimen treated with injection of gelatin solution into PA
HRCT: GE 8800
1.5 mm thickness

Visualization of pulmonary vessels on HRCT
HRCT 1.5 mm thickness

Visualization of bronchi on HRCT (Specimen study)
GE 8800
1.5 mm thickness

Visualization of bronchi and interlobular septa on HRCT

Summary Visibility of normal lung structures on HRCT

Smallest visible vessel on recent 1-2 mm HRCT
- about 200 micron in diameter
- accompanying TB or 1st order respiratory bronchiole

Smallest visible bronchi on recent 1-2 mm HRCT
- about 2 mm in diameter (small airways or bronchioles are invisible)
- cannot be seen in subpleural lung within 1-2 cm from the pleura

Visible interlobular septa
- only a few

Landmarks for localization within the secondary lobule
- PA accompanying TB & 1st RB
- Lobular border structure (PV, Interlobular septum, Pleura)
- Centrilobular area
High-resolution CT of the lung

Disease distribution within the lobule

↓

Similar information to submacroscopic pathology

↓

Accumulated knowledge of submacroscopic pathology in various lung diseases

HRCT can narrow the differential diagnosis of various lung diseases.

Limitation of HRCT (1)

Limitation of spatial resolution

Fine structures smaller than pixel size (0.4 mm)
- are not visible
- are demonstrated as a pixel with averaged CT attenuation value

Limitation of HRCT (2)

Poor tissue resolution

Cellular infiltration? Edema? Fibrosis?

Differentiation between alveolar filling process and alveolar wall thickening is difficult.

Pixel size 0.4 mm

Superior points of HRCT to pathology

- provides morphological changes of whole lung
- provides sequential changes of the same lung area

Radiological diagnosis Pathological diagnosis

Complementary role in the diagnosis of diffuse lung diseases

CT-pathologic correlation of various lung diseases
 NORMAL HRCT PATTERN

One or two branchings of PA
Lobular border PV
Some interlobular septa
Early abnormalities: difference from normal pattern

DISEASE DISTRIBUTION WITHIN THE LOBULE RECOGNIZED BY HRCT

Bronchocentric
Lymphatic spread
Hematogenous spread
Alveolar

BRONCHOCENTRIC PATTERN — BRONCHIOlar DISORDERS

- Centrilobular nodules
- Conglomerated nodules

Spared lobular border structures

- Bronchial wall thickening
- Bronchocentric
- Thickening and increased branching of intralobular BVB
- High attenuation area around BVB

CLASSIFICATION OF BRONCHIOlar DISORDERS

Primary bronchiolar disorders
- Constrictive bronchiolitis
- Acute bronchiolitis (infectious bronchiolitis)
- Diffuse panbronchiolitis
- Respiratory bronchiolitis
- Mineral dust airway disease
- Follicular bronchiolitis
- Others

Interstitial lung diseases with a prominent bronchiolar component
- Hypersensitivity pneumonitis
- RB-ILD
- Cryptogenic organizing pneumonia
- Others

Bronchiolar involvement in large airway diseases
(Ryu et al. Am J Respir Crit Care Med 2003;168:1277-1292)

INFECTIOUS BRONCHIOlITIS

Pathology
Cellular bronchiolitis + surrounding pneumonia

Diseases
- Acute and chronic infection
  Bacteria
  Mycoplasma
  Virus
  Fungus
  Mycobacteria (TB, MAC)
  etc

BACTERIAL BRONCHOPNEUMONIA

Cellular infiltration and exudate around BVB
Ill-defined centrilobular nodules
Various extension of ground-glass opacity
**Bronchopneumonia**

HRCT findings
- Centrilobular ground-glass nodules
- Intralobular branching structures
  (thickening of intralobular bronchovascular bundles)
- Lobular ground-glass opacity or consolidation
- Segmental distribution

**Mycoplasma pneumonia**

- The organism selectively attacks ciliated epithelium of the airways (central bronchi → respiratory bronchioles)
- Pathological changes
  - Cellular bronchitis and bronchiolitis
    - Exudate and neutrophils within the bronchiolar lumens
    - Metaplasia of epithelial cells
    - Chronic inflammation cells in bronchiolar wall
  - Cellular infiltration in adjacent alveoli

(Fint & Colby. Surgical Pathology of Diffuse Infiltrative Lung Diseases, 1987)

**Endobronchial spread of postprimary pulmonary TB**

**Pathological changes in TB**

- Granulomas around high-order RBs
  - Necrotizing bronchiolitis of RB

- Well-defined small nodules around high-order RBs
  - Thickening of BVB (RB level)

(Virulence of TB vs. Virulence of TB)

(Fraser and Pare. Diagnosis of Diseases of the chest, 6th ed. 1999, pp657-666)
Pulmonary TB

Early changes
- Tree-in-bud appearance

Advanced
- Small nodules
- Tree-in-bud appearance
- Conglomerated nodules
- Thickened BVB
- Cavitary consolidation

Airway invasive aspergillosis
- Patchy peribronchial consolidation
- Small ill-defined nodules
  (centrilobular nodules or tree-in-bud)
- Areas of ground-glass opacity
- Invasion of aspergillus to airway wall
- Resultant inflammation and necrosis

Diffuse panbronchiolitis
- Centrilobular nodules
- Inflammatory nodules with foamy macrophages around 1st-order RB

Follicular bronchiolitis

Associated diseases
- Collagen vascular diseases (rheumatoid arthritis)
- Immunodeficiency (AIDS)
- Nonspecific response to airway inflammation

Histology
- Hyperplasia of BALT
- Polyclonal lymphoid aggregates along the bifurcation of bronchioles and along the pulmonary lymphatics

Follicular Bronchiolitis

HRCT findings
- Centrilobular nodules or GGO
- Intralobular branching structures
- Bronchial wall thickening
- Lower lobe predominance
Interstitial lung diseases with a prominent bronchiolar components

Pathology
Peribronchiolar inflammation and fibrosis
(or perilymphatic, perivascular disease)

Diseases
- Hypersensitivity pneumonitis
- Respiratory bronchiolitis
- Respiratory bronchiolitis with interstitial lung disease (RB-ILD)
- Pneumoconiosis
  - siderosis
  - simple coal worker’s pneumoconiosis

Hypersensitive pneumonitis

Pathology
- Cellular bronchiolitis
- Chronic bronchiocentric cellular interstitial pneumonia (lymphocytic)
- Small poorly-formed non-caseating granuloma

CT findings
- Poorly defined small centrilobular nodules
- Symmetric or diffuse bilateral ground-glass opacities
- Lobular areas of decreased attenuation and vascularity on inspiratory image
- Air trapping on expiratory image

Welder’s pneumoconiosis

Pathology
- Iron-laden macrophages in peribronchiolar interstitium (and in the alveolar space in severe case)
- Little or no fibrosis in pure siderosis

HRCT findings
- Ground-glass centrilobular nodules
- Intralobular branching structures
- Diffuse or mid-lung zone predominance

Lymphatic spread pattern

- Bronchial wall thickening
- Nodular or diffuse thickening and increased branching of bronchovascular bundles
- Nodular or diffuse thickening of interlobular septa and pleura
- Alveolar area is spared

Diseases that show lymphatic spread

Cellular infiltration
- Lymphangitic carcinomatosis
- Lymphoproliferative disorders
- Leukemic infiltration
- Acute eosinophilic pneumonia

Granuloma
- Sarcoidosis
- Pneumoconiosis

Edema
- Pulmonary edema (interstitial)
Lymphangitic carcinomatosis

- Tumor in peribronchovascular interstitium and peripheral interstitium
- Spared alveolar wall
- Thickening of BVB and interlobular septa

Specimen CT

In vivo HRCT

Secondary pulmonary lobule

Sarcoidosis

- Non-necrotizing granulomas in peribronchovascular interstitium and peripheral interstitium
- Irregular or nodular thickening of BVB, interlobular septa, and pleura

Histology

- Granulomas around small BVB
- Ground-glass opacity

Hematogenous spread pattern

Small nodules in random distribution

Hematogenous metastasis

- Tumor emboli in small PA (< 100 micron)
- Any location (small nodule)
- Small nodules in random distribution
Miliary tuberculosis

Alveolar pattern → Alveolar wall thickening → Alveolar space filling

Ground-glass opacity → Consolidation

Diseases showing alveolar pattern
- Infections
- Non-infectious inflammation
- Circulation abnormalities
- Tumors

Pneumocystis pneumonia → IP related to PSS

Clues for differential diagnosis of alveolar pattern
- Predominance Disease of distribution in the lung
  - Upper or Lower, Inner or Outer, Dorsal or Ventral, Segmental or Non-segmental
- Co-existence of bronchocentric or lymphatic spread pattern
- Co-existence of remodeling of lung structures

Clinical information
- Severity, Sequential changes
- Laboratory data (WBC, CRP, etc.)
- Accompanying diseases (malignancy, collagen diseases)
- Immunological condition
- Drugs

IPF (Idiopathic Pulmonary Fibrosis) = UIP

Histologic features
- Lymphocytic infiltration in alveolar wall
- Dense collagen deposition, Fibroblastic foci, Smooth muscle proliferation, Cyst formation

Morphological features
- Spatial and temporal heterogeneity
- Structural remodeling
- Lower lobe and subpleural predominance

Uneven mixture of normal lung, various degrees of fibrosis, honeycomb lung

Pathology of UIP
IPF (UIP)

- Patchy distribution (normal and fibrosis)
- Cystic changes with thick wall
- Reticular changes
- Ground-glass opacity

- Cysts with fibrotic wall
- Even distribution of fibrotic changes
- Micocystic changes
- Various degree of fibrosis

New Classification of Idiopathic Interstitial Pneumonia (ATS/ERS, Am J Respir Crit Care Med 2002)

Importance of CRP diagnosis

Clinician
- Clinical findings

Radiologist
- Radiological findings

Pathologist
- Pathological findings

Diagnosis