Collapse, Crowding, Consolidation, and Contrast: Imaging Findings of Atelectasis on Computed Tomography

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Goals and Objectives

• Define atelectasis

• Describe direct and indirect findings of atelectasis on computed tomography (CT)

• List different types of atelectasis

• Illustrate pathology which may be obscured by atelectatic lung

• Identify common and uncommon mimics of atelectasis on CT
Atelectasis and Signs of Volume Loss

• Atelectasis = Collapse of all or part of the lung

  • Direct Signs
    • Fissure displacement
    • Bronchovascular crowding

  • Indirect Signs
    • Increased lung opacity
    • Ipsilateral mediastinal shift
    • Compensatory hyperinflation
    • Hilar displacement
    • Elevation of the ipsilateral hemidiaphragm
Direct Signs of Atelectasis

Contrast-enhanced CT (CECT) shows left lower lobe atelectasis due to endobronchial mucus plugging, with fissure displacement (white arrow) and bronchovascular crowding, direct signs of volume loss. 3-month follow-up CT shows re-expansion of previously atelectatic left lower lobe and a normal position of the left major fissure (black arrow).
Indirect Signs of Atelectasis

Axial and coronal CECT show indirect signs of right upper and middle lobe atelectasis, including increased lung opacity (white arrows), ipsilateral mediastinal shift, hemidiaphragm elevation, hyperinflation of adjacent lung (*), and hilar displacement. Note juxtaphrenic peak (black arrow) on the coronal CT from fat being drawn into an inferior accessory fissure.
Types of Atelectasis

- Resorption / Obstructive
- Relaxation / Compresssive or Passive
- Gravity dependent
- Adhesive
- Rounded
- Cicatricial
Resorption / Obstructive Atelectasis

• Resorption of air distal to airway obstruction
  • Endobronchial lesion (mucus, neoplasm, foreign body, stenosis/fibrosis)
  • Extrinsic compression (neoplasm, lymphadenopathy, infection/inflammation)

• Alveolar air resorbed by capillary circulation in atelectatic lung, not replaced by inspired air
Resorption / Obstructive Atelectasis

• Acute bronchial obstruction
  • Lobar atelectasis occurs within 24 hours in healthy lungs on room air
  • Lobar atelectasis may occur within an hour in intubated patients on 100% O2

• Chronic bronchial obstruction
  • Pneumonitis distal to obstructing lesion, usually lung cancer
  • “Drowned Lung” → Negative intrathoracic pressure causes fluid migration into atelectatic lung with little to no volume loss; may also occur with acute bronchial obstruction

• “Ball-valve” obstruction
  • Airway lesions (tumors or polyps) resulting in dynamic airway obstruction
  • Higher pressure gradients required to overcome obstruction
  • Rapid alveolar air resorption and atelectasis
Resorption / Obstructive Atelectasis

• Large airway obstruction
  • Does not always produce atelectasis
  • Collateral ventilation between segments and between lobes that lack a complete fissure may allow an obstructed lobe or segment to remain aerated

• Small airway obstruction
  • Larger airways remain patent and aerated → air bronchograms within atelectatic lung
  • When secretions accumulate, air is replaced by mucus in the bronchi
Resorption / Obstructive Atelectasis

CECT shows left lower lobe atelectasis due to endobronchial obstruction; note posteriorly displaced major fissure (white arrows) and diffuse lung enhancement. Small tubular and round low attenuation foci within segmental bronchi represent mucus-filled bronchi (black arrow).
Relaxation / Compressive Atelectasis

• Relaxation (passive) atelectasis
  • Lung compression by space occupying process (pleural fluid, pneumothorax)
  • Lung volume reduced to its natural non-aerated state
  • Some authors reserve the term “passive” atelectasis for when a pneumothorax is the culprit, implying passive loss of alveolar elastic recoil due to loss of negative intrathoracic pressure

• Compressive atelectasis
  • Often used interchangeably with “passive” and “relaxation” atelectasis
  • Reduction in lung volume beyond its natural relaxed state
Relaxation Atelectasis

CECT shows lower lobe atelectasis (asterisks) due to hemothorax. Hyperattenuation in the dependent pleural space represents blood products (arrows). Note that atelectatic lung always collapses “inward” toward the hilum. High attenuation in the dependent pleural space is either blood or enhancing tumor, and should not be confused with atelectasis.
Axial and coronal CT demonstrate LLL opacities (black asterisks), adjacent to an elevated left hemidiaphragm, consistent with compressive atelectasis. Elevation of the left hemidiaphragm was secondary to phrenic nerve injury with resultant diaphragmatic paralysis.
Gravity-Dependent Atelectasis

• Alveolar collapse in gravity-dependent portions of lung
  • Gravitational forces result in alveolar collapse and subpleural ground-glass opacities or nodularity
  • Changes in patient position (from supine to prone) resolves this abnormality and excludes subpleural fibrosis
Dependent atelectasis manifests as linear and ground-glass opacities (arrow) on inspiratory CT (left image). Prone imaging (right image) counters the gravitational effect with resolution of the previously seen posterior opacities, now seen anteriorly in the dependent lung.
Adhesive Atelectasis

- Reduced surface tension results in alveolar collapse
  - Surfactant abnormality (infant respiratory distress syndrome)
  - Acute respiratory distress syndrome
  - Post-operative, especially following CABG
  - Pneumonia, smoke inhalation, thromboembolism, acute radiation pneumonitis
Adhesive Atelectasis

AP chest radiograph and CT show confluent opacities and volume loss of the right lung and left lower lobe consistent with adhesive atelectasis due to infantile respiratory distress syndrome. Left upper lobe lucencies represent pulmonary interstitial emphysema (asterisks).
Rounded Atelectasis

• Folded atelectatic lung with fibrous bands and adhesions to the visceral pleura
  • Most commonly caused by occupational exposure to mineral dusts
  • May follow exudative pleuritis of any etiology

• Imaging criteria
  • Mass-like or rounded peripheral opacity abutting the pleura
  • Adjacent pleural abnormality including thickening and effusion
  • “Comet tail sign” – vascular convergence into the lesion
  • Volume loss
Rounded Atelectasis

CECT shows a right lower lobe subpleural nodule (arrow) adjacent to pleural thickening and calcification and bronchovascular structures (curved arrows) producing the “comet tail” sign. Note posterior displacement of the right major fissure relative to the contralateral side (orange arrow) indicating volume loss. Stability over 10 years and negative PET confirm benign etiology.
Cicatricial Atelectasis

• Reduction in alveolar volume from fibrosis or scarring
  • Localized
    • Typically one or more lobes
    • Reduced lung volumes, scarring and traction bronchiectasis
    • Increased opacity of affected lung, hyperinflation of unaffected lung
    • Common causes: Tuberculosis (typically upper lobes), necrotizing pneumonia, radiation fibrosis (limited to radiation port)
  • Diffuse
    • Reduced lung volumes and reticulation
    • Hyperinflation of unaffected lung
    • Caused by interstitial lung disease
Cicatricial Atelectasis

Axial and coronal CT demonstrate right upper lobe radiation fibrosis with intrinsic traction bronchiectasis, architectural distortion and fissure displacement (arrow).
Mimics and Hidden Pathology

- Mimics and entities obscured by atelectasis
  - Neoplasm
  - Pneumonia (infectious/aspiration)
  - Inflammation (e.g. vasculitis, granulomatous disease)
  - Infarction

- Identification of direct and indirect signs of volume loss
  - Most entities are space-occupying lesions

- Enhancement characteristics on CECT
  - Atelectatic lung enhances more than infectious/inflammatory consolidations, infarctions, and most tumors
  - Intense enhancement of atelectatic lung relates to increased blood flow per unit area of collapsed lung, attributed to bronchovascular crowding
Left Upper Lobe Collapse

CECT shows a mass (white arrow) within an atelectatic left upper lobe (asterisk). Proximal extension of the mass into the left mainstem bronchus produces the “tip of the iceberg” sign (orange arrow), an important clue to the presence of an endobronchial lesion. The atelectatic lung enhances to a greater degree than the tumor. PET demonstrates an FDG-avid mass, proven to represent a primary pulmonary diffuse large B-cell lymphoma on biopsy.
Atelectasis + Pneumonia

CECT of a patient with atelectasis and pneumonia shows closely apposed pulmonary vessels in atelectasis that result in homogeneous hyperenhancement (asterisk), in contrast to the hypoenhancing pneumonia (arrows), and the absence of enhancement in necrotizing pneumonia (curved arrows).
Atelectasis + Pneumonia

CECT (lung window) shows similar appearing lingular and left lower lobe consolidations. Use of soft tissue window settings allows differentiation between the densely enhancing left lower lobe atelectasis and the poorly enhancing lingular pneumonia (curved arrow).
Atelectasis + Infarction

CECT demonstrates a large left lower lobe wedge-shaped infarct (curved arrows) with adjacent combined relaxation and adhesive atelectasis (asterisks). Note the pulmonary embolus within the left lower lobe pulmonary pulmonary artery (arrow).
Atelectasis + Infarction

CECT shows hyperenhancing lower lobe atelectasis (asterisks). Tubular and wedge-shaped low attenuation lesions (arrow) represent mucus filled bronchi and pulmonary infarcts. Left lower lobe cavitary lesion (curved arrow) represents a pulmonary infarct. Necrotizing pneumonia and malignancy would be included in the differential diagnosis for the cavitary lesion.
CECT of a patient with renal cell carcinoma shows an enhancing nodule likely along the visceral pleura (arrows) adjacent to an atelectatic right lower lobe (asterisks). Bilateral pleural effusions result in relaxation atelectasis. In contrast to most primary and metastatic pulmonary malignancies, renal cell carcinoma metastases are hypervascular and may enhance more than atelectatic lung.
Atelectasis + Endobronchial Neoplasm

CECT shows a heterogeneously enhancing partially calcified small cell lung carcinoma (arrow) that completely obliterates the left lower lobe bronchial lumen and produces lobar atelectasis. Although the mass and the atelectatic lung exhibit similar enhancement, the diagnosis of malignancy is made possible by identification of the convex bulge caused by the mass (S sign of Golden).
Rounded Atelectasis vs Lung Cancer

CECT shows a right lower lobe subpleural mass. Note the absence of the “comet tail” sign, an important imaging criterion for the diagnosis of rounded atelectasis. In addition, heterogeneous enhancement with central hypoenhancement (arrow) suggests necrosis and favors lung cancer over rounded atelectasis. Biopsy showed non-small cell lung cancer.
Rounded Atelectasis vs Lung Cancer

CECT shows a left upper lobe rounded opacity that crosses the fissure into the left lower lobe. Left lung volume loss and adjacent pleural thickening might suggest rounded atelectasis, but the lesion does not completely abut the pleural surface. PET was performed showing FDG avidity in the lesion and the adjacent pleura. Biopsy confirmed lung adenocarcinoma.
Summary

• Atelectatic lung produces signs of volume loss including bronchovascular crowding and fissural displacement

• Assessment of enhancing patterns on CECT is useful for the differentiation of atelectatic lung from other disease processes: Atelectatic lung enhances homogenously, whereas other entities (neoplasm, infection/aspiration, infarct) exhibit heterogeneous or no enhancement

• Assessment of atelectatic lung on CECT may allow identification of intrinsic abnormalities that may be obscured by surrounding atelectasis.

• Identification of ancillary findings helps formulate a focused differential diagnosis (e.g., pulmonary artery filling defects, mediastinal lymphadenopathy, traction bronchiectasis, comet tail sign, pleural effusion/thickening, etc.)
References

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