Imaging findings of thoracic cavitating and cystic lesions

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Objective

• The purpose of this article was to summarize the imaging findings of cavitating and cystic lung lesions.

Materials and Methods

• We reviewed cases with cavitating and cystic lung lesions that underwent CT (computed tomography) at our institution, and summarized image findings and clinical manifestations of them.
Definition of the term “cavity”

- A “cavity” is a gas filled space, seen as a lucency or low attenuation area, within pulmonary consolidation, a mass, or a nodule.
- A “cavity” is usually produced by the expulsion or drainage of a necrotic part of the lesion via the bronchial tree, which sometimes shows a air-fluid level.

Definition of the term “cyst”

- A “cyst” is a round parenchymal low attenuating area with a well defined interface w/ normal lung.
- “Cysts” have variable wall thickness but are usually thin-walled ( < 2 mm) and occur w/o associated pulmonary emphysema.
- A “cyst” usually contain air but occasionally contain fluid or solid material.

# Cavitating lung lesions

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*GPA: granulomatosis with polyangitis

## Cystic lung lesions

- Langerhans cell histiocytosis (LCH)
- Lymphangioleiomatosis (LAM)
- Follicular bronchiolitis, Lymphocytic interstitial pneumonia
- Amyloidosis
- Birt-Hogg Dubé syndrome
- Pneumocystis pneumonia (PCP)
- Congenital pulmonary airway malformation (CPAM)
Cavitation in lung cancer has been reported up to 22%\(^2-4\).

Histologic type\(^2-4\):
- 80% - squamous cell carcinoma
- 20% - adenocarcinoma & large cell carcinoma
  (small cell carcinoma with cavity is very rare.)

Lung cancer with cavity has been associated with a worse prognosis.

**Association of wall thickness between benign and malignant cavitating lesions**

- Typical characteristics of cavitating\(^5\):
  - Benign lesions; smooth, thin walls
  - Malignant lesions; thick, irregular walls
- 95% of cavitary nodules with a wall thickness > 15 mm are malignant.
- 92% with wall thickness < 5 mm are benign\(^5\).

The incidence of malignancy\(^4,5\):
- Wall thickness of cavity
  - 1 mm: 8%
  - 5-10 mm: 50%
  - >15 mm: 95%
Association of other findings between benign and malignant cavitating lesions\textsuperscript{4,5})

Suggestive of malignant cavity

- Contour of cavity wall irregularity (inner/outer), enhancing mural nodules
- Persistent obstructive pneumonitis
- Invasion to the adjacent structures
- Presence of distant metastasis

Suggestive of benign cavity

- Linear or well defined margins
- Bronchial wall thickness

Axial CT images shows a peripheral cavitating mass w/ thick, irregular wall in the left lower lobe.
- Type I, III, IV, V are useful for differentiating lung cancer from single pulmonary tuberculosis w/ thick walled cavity.
- The frequencies of type I, III in lung cancer were higher than in tuberculosis.
- The frequencies of type IV, V in tuberculosis were higher than in lung cancer.
Aspergilloma vs lung cancer

**Aspergilloma**
- unenhanced mural nodule
- thin wall
- dependent location of a mural nodule
- adjacent bronchiectasis
- volume loss of the involved lobe

**Lung cancer**
- enhanced mural nodule
- thick wall

[Images of aspergilloma and lung cancer with CT scans showing differences in mural nodules and wall thickness.]
Pulmonary metastasis

- At CT, the most common pulmonary mets w/ cavity is squamous cell carcinoma of head and neck origin or less commonly pelvis or esophagus, followed by adenocarcinoma 4).

- Tumor necrosis or a check valve mechanism could result in cavity formation 8).

- Metastatic sarcomas can cavitate, and a pneumothorax can occur as a complication 8).

- Chemotherapy also could induce cavitation 8).

- the characteristics of the cavity wall varies from thick and irregular to very thin and smooth like cyst 2).

When single large cavitating metastasis are seen on CT, DDX:
- chronic abscess
- primary neoplasm
- tuberculosis
- When multiple small cavitary metastases are seen on CT, DDX:
- rheumatoid nodules
- septic emboli
Mycobacterium tuberculosis (TB)

< Post-primary tuberculosis >
- Cavitation is a hallmark of post-primary TB, which occurs in 40-50% of the patients \(^{2,4,9,10,11}\).
- Cavitation indicates active, and higher infectivity \(^{4,9,11}\). Cavity could result in bronchopleural fistula, or fungal infection, mycetoma \(^9\).

Cavity of TB \(^{2,4,10}\)
1) Wall can be thin and smooth, or thick and nodular.
2) Multiple cavities are typically located in the apical and posterior segments of the upper lobes, or the apical segment of the lower lobes.
3) Air-fluid level in the cavity suggests bacterial or fungal superinfection.

![TBc](image)

Axial CT demonstrates a cavity with thick wall (arrow head) in the apical segment of the left lower lobe. Multiple centrilobular nodules are seen adjacent to the cavity (arrows).
Non-tuberculous mycobacterial (NTM) infection

- The differentiation of the cavities of NTM from Tb is difficult on CT\(^9\). Although, there are some reports about the differences of the characteristics of cavity between the two diseases\(^9,12\); NTM tend to have smaller, thinner cavities.

- Other differential point between Tb and NTM\(^4,12,13\).
  1) Bronchiectasis in the middle lobe and lingula w/ centrilobular nodules (non classical NTM), typically affects elderly women.
  2) Upper lobe cavitary lesions (classical NTM), typically affects elderly men with COPD, like emphysema.
NTM

A: CT demonstrates a cavity with smooth wall in the right upper lobe (arrow head). Tiny nodules surrounding the cavity are also seen (arrow).
B: CT demonstrates bronchiectasis manly in the middle lobe (arrow), and centrilobular nodules in the right lower lobes.
Bacterial Infection

- The most common community acquired bacterial pneumonias, *Streptococcus pneumoniae, Haemophilus influenzae*, do not cavitate typically, however these pneumonia could be a relatively common cause of cavitation due to their high incidence \(^3,4\).
- Pneumonia caused by *Streptococcus pneumoniae* *w/ Pseudomonas aeruginosa* makes cavitation more frequently than that caused by *Streptococcus pneumoniae* alone, *w/ Haemophilus influenzae, w/ methicillin-susceptible Staphylococcus aureus* \(^14\).
- *Klebsiella pneumoniae* is frequently complicated by lung abscess, and makes multiple small cavities. The cavities could coalesce into one large cavity \(^3,4\).
Uncommon bacterial infections include actinomycosis, nocardiosis, melioidosis, and cause cavitation.  

<Actinomycosis>

- Aspiration of endogenous organisms of the oropharynx into the lung with poor oral hygiene have been associated with Actinomyces infection.
- Typical CT features of the pulmonary actinomycosis are mass or consolidation with central low attenuation area and adjacent pleural thickening. Multiple small cavities may develop. Actinomycosis could spread from the lung to the pleura, mediastinum and chest wall, as this disease produce proteolytic enzymes, and result in empyema, invasion into the chest wall.
Uncommon bacterial infections include actinomycosis, nocardiosis, melioidosis, and cause cavitation ²⁻⁴).

<Nocardiosis ²⁻⁴>}

- Multiple or solitary cavitary nodules may develop more often in the upper lobes.
- Cavitation may be seen among the patients with advanced human immunodeficiency virus than those with other hosts, more frequently.
- Ground glass opacity and consolidation are also seen on CT.
- Nocardiosis could cross fissures, and invade the pleura, chest wall, and mediastinum, that result in empyema, like actinomycosis.
Lung abscess

- An abscess is predominantly caused by anaerobic and microaerophilic components of the oral flora, and often polymicrobial, such as *Streptococcus milleri*, *Fusobacterium*, *Klebsiella pneumoniae*\(^3,4\).  

CT features of lung abscess

- Fluid filled mass, or mass with air-fluid level can be seen.
- Relatively thick wall, smooth border.
- Consolidation surrounding the mass can be seen.
Lung abscess

A: Axial CT shows consolidation in the left upper lobe.
B: Axial CT (obtained at a lower level than A) shows a cavity with air-fluid level. Cavity wall is thick, but inner border is smooth.
Septic pulmonary embolism (SPE)

- Septic pulmonary embolism is associated with following factors; tricuspid valve endocarditis, septic thrombophlebitis, suppurative process in the head and neck, indwelling intravenous catheters \(^4\), \(^{18}\).

- Lemierre syndrome, that consists of internal jugular vein thrombosis after a primary oropharyngeal infection with the development of distant septic emboli, may be involved could be considered in an adolescent or young adult with sore throat or neck pain, fever, and lung lesions.

CT features of SPE

- multiple peripheral or subpleural nodular opacities, with or without cavitation.
Septic pulmonary embolism

Axial CT demonstrates multiple peripheral and subpleural nodules with or without cavitation (arrows). Bilateral pleural effusion is also seen.
Pulmonary Aspergillosis (PA)

- PA is caused by *Aspergillus* species, typically *A. fumigatus* \(^2,3,19,20\).

< Types of PA >

1) aspergilloma
2) semi-invasive aspergillosis  
   (chronic necrotizing)
3) invasive aspergillosis  
   (angioinvasive and airway invasive)
4) allergic bronchopulmonary aspergillosis  
   (ABPA)

- semi-invasive and invasive PA is more frequently seen in patients w/ hepatic failure, diabetes mellitus, bone marrow transplantation, leukemia, and AIDS.
Pulmonary Aspergillosis (PA)

Aspergilloma

- *Aspergillus* infection w/o tissue invasion.
- Aspergilloma (fungus ball) consists of mycelia, inflammatory cells, fibrin, debris, and formed within a pre-existing lung cavity, such as tuberculosis, sarcoidosis, bulla or bronchiecataxis.

CT features of Aspergilloma

- Air crescent sign; a rim of air space between the peripheral dead tissue mass.
- The aspergilloma is usually a dependent, mobile mass, and unenhanced.
- Often associated with thickening of the cavity and adjacent pleura, that could be due to hypersensitivity reaction.
Aspergilloma

A) CT shows a large cystic cavity in the right upper lobe.

B, C) 1 year later than A). CT shows a poorly defined component in the cavity w/ thick wall, surrounded by pleural thickening, and centrilobular nodules.

D, E) 6 months later than B, C), the fungus ball (arrowhead) in the cavity grows larger, and demonstrates “air crescent sign” or “meniscus sign” (arrows).
Pulmonary Aspergillosis (PA)

semi-invasive aspergillosis

< CT features >^{3,4,19)}

- Uni. or bilateral consolidation or mass, w/ or w/o cavitation, adjacent pleural thickening and lung distortion.
- Cavity expands and paracavitary infiltrates occur w/ a progressive functional lung loss.

invasive aspergillosis

< CT features >^{3,4,19,20)}

- Solitary or multiple nodules surrounded by hemorrhagic GGO (= halo sign), or peripheral pleural based consolidation, which results from infarcts.
- Cavitation occurs in the lesions, as the neutrophil count recovers (= air crescent sign), implies favorable prognosis.
Invasive aspergillosis

A) CT shows pleural based ground glass nodules with surrounding dense attenuation in the right lower lobe (arrows). These findings are known as “reversed halo sign”. Small pleural effusion is also seen.

B) 2 months later. Those lesions become smaller and have cavity (arrow head).
Bulla with air-fluid level

- The formation of air-fluid level in known bullae could be result from fluid accumulation secondary to the adjacent lung infection.
- Some cases could diminish or disappear, after clearing of the fluid accumulations.
- The inflammatory process probably leads to complete occlusion of the bronchial communication and subsequent resorption of air \(^{21}\).

A) CT shows bullae in bilateral upper lobes.  
B) 3 months later. CT shows thick walled bullae with air-fluid level. Adjacent consolidation is also seen.  
C) 4 month later. Infected bullae almost disappear.
Granulomatosis with polyangitis (GPA)

- GPA is the most common of the antineutrophil cytoplasmic antibodies (ANCA) associated vasculitis, that involves mainly small and medium sized vessels \(^{22-26}\).

- The classic clinical triad is,
  1) Upper airway involvement (sinusitis, nasal obstruction, rhinorrhea, ulceration)
  2) Lower airway involvement (cough, hemoptysis, dyspnea)
  3) Glomerulonephritis

- The upper respiratory tract is involved in almost all cases, and lungs in 90%, kidneys in 80% of cases \(^{22-26}\).
Granulomatosis with polyangitis (GPA)

- CT findings of GPA in the chest

1) Nodules or masses
- The most common radiographic and CT features (seen in 90% of cases)
- They are composed of granulomatous tissue, in active disease.
- multiple, bilateral, and mainly subpleural distribution
- No predilection for the upper or lower lung zones.
- may have smooth or less commonly, irregular margins.
- 25%-50% of nodules larger than 2 cm are cavitated on CT. The wall of cavities are thick w/ irregular inner margin, but could be thin walled and decrease in size w/ treatment. Cavity may contain air-fluid level if secondarily infected.
- Hemorrhage as ground glass opacity may occur around the nodules (halo sign).
- Reversed halo sign also could occur, reflecting an organizing
Granulomatosi with polyangitis (GPA)

- CT findings of GPA in the chest 

2) Ground glass opacity (GGO) & Consolidation
- Diffuse GGO and consolidation occur in up to 50% of cases.
- These findings may result from pulmonary hemorrhage or infection, infarcts and organizing pneumonia.
- Typical distribution of GGO and consolidation is as follows; bilateral perihilar, peribronchovascular.
- As with nodules and masses, GGO and consolidation may also wax and wane regardless of therapy.

3) Airway involvement
- Late complication of GPA, that occurs in 15-25% of cases.
- Subglottic tracheal stenosis is most commonly affected.
- Concentric wall thickening may lead to airway stenosis, could be circumferential, and be smooth or irregular. Involvement of the posterior membrane of the trachea is the key point.
Granulomatosis with polyangitis (GPA)

Axial CT demonstrates multiple pulmonary nodules with peripheral predominance. One of them forms a lobulated cavity, which has thin smooth wall and septum (arrow).
Lymphangioleiomyomatosis (LAM)\textsuperscript{27,28}

- LAM is characterized by diffuse pulmonary cysts.
- Occurs almost all in women of childbearing age.
- Characteristic histological findings of proliferation of atypical smooth muscle cells "LAM cells".
- Pulmonary LAM can occur as part of the tuberous sclerosis complex.
- Representative complications
  1) Pneumothorax 2) Chylothorax 3) Hemoptysis

CT findings of chest

Cysts
- Multiple pulmonary round and thin walled cysts
- Cysts are symmetrically and uniformly distributed in entire lung.
- The lung parenchyma between the cysts is normal, however small nodules, reticulation, or GGO can appear in highly cellular forms with significant smooth cell proliferation, or hemorrhage or edema.

Others
- Recurrent pneumothorax
- Chylothorax (unilateral or bilateral, large and recurrent)
Axial CT demonstrates multiple thin walled cysts in the bilateral lungs, which are diffuse, and distributed randomly. The lung parenchyma among the cyst is normal.

Abdominal CECT demonstrates bilateral multiple nodules and masses with fat attenuation (arrows), that is typical CT findings of renal angiomyolipomas.

NECT of the brain shows the subependymal calcifications (arrows), the finding of tuberous sclerosis.
Birt-Hogg-Dubé Syndrome \textsuperscript{30,31} (BHD syndrome)

- BHD syndrome is a rare autosomal dominant systemic disorder.
- Cutaneous lesions, renal neoplasms, and multiple cysts in the lung are seen in the BHD patients.
  - Cutaneous lesion: multiple whitish papules on the head, neck, face, and upper trunk in the 3\textsuperscript{rd} to 4\textsuperscript{th} decades of life.
  - Renal neoplasms: multiple, bilateral tumors are often seen. hybrid chromophobe oncocytomas (50%), chromophobe carcinomas (34%), clear cell carcinomas (9%), oncocytomas, and papillary renal cell carcinomas.
  - Lung cysts: pneumothorax could occur (33-38%).
Birt-Hogg-Dubé Syndrome\(^ {30,31}\) (BHD syndrome)

CT findings of chest

Cysts
- Lung cysts have been reported in 77-89% of BHDs.
- Mainly bilateral (87%), and multiple
- Lower lobe predominant, and no central or peripheral predominance
- Variable size, and shapes (round, oval, lentiform)
- The large dominant cysts tend to be located in the lung bases and could be lobulated, multiseptated.
- Walls of cyst are thin and uniform

Pneumothorax
- Seen as complication of BHD syndrome
BHD syndrome

Multiple bilateral pulmonary cysts are seen predominantly in lower lobes.

Bilateral small pleural effusion are due to abdominal surgery.

Abdominal CT demonstrates bilateral multiple renal tumors.
Conclusion

• The cavitating lung lesions had some characteristic findings. To know this information could be useful for diagnosis of these lesions.

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