COPD in Radiology, with a Focus on Bronchiectasis and Emphysema

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Why is COPD important?

• Its common:
  – 30 million Americans living with chronic lung disease.
  – 13.8 million American men and women have chronic bronchitis.
  – Nearly 2 million have emphysema from a 1993 National Health Survey.

• It affects lives:
  – 114 million days of restricted activity due to chronic bronchitis and emphysema in the same survey. This is 312,000 person / years lost.

• It can be fatal:
  – In 1993, there were 95,900 deaths from COPD.
  – This made it the 4th leading cause of death in the United States.

Who is at risk for COPD?

- **Smokers**
  - Tobacco smoke accounts for 80-90% of the risk for developing COPD.
  - But only 10-15% of smokers develop clinically significant COPD.
  - The reason for this remains unknown.
- Men > Women – even when controlling for smoking.
- M + M is inversely proportional to socioeconomic status.
- COPD aggregates in families, even with alpha\(_1\)-antitrypsin deficiency is excluded.
- Atopic Individuals are at increased risk for all forms of COPD, not just asthma.
- Occupational Hazards.
- Children of mother’s who smoke, low birth weight, and frequent childhood pulmonary infections.

Natural History of COPD

- FEV1 of < 0.8 L usually produces symptomatic dyspnea.
- Nonsmokers lose FEV$_1$ at an accelerating rate with age; the average loss is about 30 mL/year.
- 30 cigarettes/day average a slightly greater rate of decline.
- A susceptible smoker who stops smoking at age 50 loses function at the rate for nonsmokers.
- The ex-smoker on this graph delayed onset of dyspnea by 11 years after quitting at age 50.

Definitions

• **Chronic bronchitis**
  – Epidemiologically = presence of chronic productive cough for 3 months in each of 2 successive years.
  – No other underlying cause, e.g., *M. tuberculosis*, carcinoma of the lung, bronchiectasis, cystic fibrosis, and chronic congestive heart failure.

• **Emphysema**
  – “A condition of the lung characterized by abnormal, permanent enlargement of the air spaces distal to the terminal bronchiole, accompanied by destruction of their walls and without obvious fibrosis.” – *RCoNA, 36:1, 1998 pg. 15.*

• **Asthma**
  – “Asthma is a chronic inflammatory disorder of the airways…. In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing…. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. [Also with] bronchial hyperresponsiveness.” – *M and N, pg. 1248.*
  – Asthma must have limited air flow.
  – Emphysema and chronic bronchitis may be diagnosed without air flow limitation.

• **Bronchiectasis**
  – Morphologic definition = Permanent dilatation of bronchi.
  – Cylindrical or tubular, vericose, and saccular or cystic.
Clinical History

• Cough is the most frequent symptom.
  – Usually dyspnea causes patients to seek medical attention.
• Chronic bronchitis is the most common cause of hemoptysis in the United States.
  – Usually in association with an infective episode.
• COPD is a functional / clinical diagnosis.
  – Radiology can only suggest this diagnosis.
• Median survival in a Finnish population after the first hospital admission for COPD was 5.7 years.
Complications – 1 Bullae

- P.L. is a 45 year old woman, s/p thoroscopic right apex wedge resection for a small pulmonary nodule. Chest tube in place.
- Bullous changes in the left apex.
- BIDMC Exam

Courtesy of Dr. Phil Boiselle.
Complications – 1.1 Bullae

- Same patient as previous slide.
- CT shows extent of bullous changes in the left apex.
- Post-surgical changes are seen on the right.
- Patients with pulmonary bullae are at increased risk for pneumothorax and pulmonary infections.
- BIDMC Exam

Courtesy of Dr. Phil Boiselle.
Complications - 2

**Pneumothorax**

- Patients with COPD have poor pulmonary reserve.
- Suspect pneumothorax in a patient with COPD who has sudden increase in symptoms. Spontaneous pneumothorax in a normal person is usually not dangerous; in COPD it can be life threatening.
- May be difficult to treat pneumothorax in COPD if there is a bronchopleural fistula.
- Remember expiration films can help clarify the diagnosis.
- Large bullae can mimic pneumothorax.
  
  - Review old films!

Complications – 2.1

Where is the abnormality?

Pneumothroax in the LLL in a patient with moderate/severe COPD.

Courtesy of Dr. Chad Brecher, Chief Resident BIDMC Radiology.
Complications - 3

Cor Pulmonale

- Alveolar hypoxia $\rightarrow$ increased pulmonary vascular resistance.
  - Emphysema also leads to loss of vascular bed.
- Acidemia locally in the lung can also contribute to increased pulmonary vascular pressures.
- Hypoxia $\rightarrow$ erythrocytosis $\rightarrow$ increased blood viscosity.
- Increased intrathoracic pressure secondary to air trapping may also increase right heart strain. Usually a minor effect.

Diagnosis of Cor Pulmonale

- Can diagnose on CXR, EKG, palpation of the heart, prominent and split S2, etc.
- Rx = $O_2$ acutely and at home.

Complications – 3.1

- PA shows enlargement of the main pulmonary artery (black arrow) and right pulmonary artery (black arrow).
- Peripheral pulmonary arteries are reduced in caliber.
- Lateral shows enlargement of both the right (short) and left (long black arrows) pulmonary arteries.
- White arrow shows right ventricular enlargement.

http://brighamrad.harvard.edu/Cases/bwh/hcache/213/full.html
Complications - 4

**Pneumonia**

- Data are sparse, but generally agreed that pneumonia is more common in patients with COPD.
- All types of pneumonia seem to be increased.
- Evidence that treating with empiric antibiotics helps COPD flares???

**Sleep Disorders**

- Common and a major source of morbidity.
- Nighttime hypoxia may contribute to pulmonary hypertension.

Lung Anatomy

Lung buds at 4 weeks –
Grey’s Anatomy, plate 948

Lung buds a few divisions later –
Grey’s Anatomy, plate 949

- Trachea → main stem bronchi → segmental bronchi → bronchioles → respiratory bronchioles → alveoli.
- There are 500,000 respiratory bronchioles.
- Each respiratory bronchiole has a diameter of 0.04 cm.
- The area of respiratory bronchioles is 1000 cm².
Brochiectasis

- Bronchiectasis is **irreversible dilatation of the bronchial tree**.
- The disease may cause chronic sputum production and hemaoptysis or be may be asymptomatic.
- **DDx** is extensive. Morphological findings of bronchiectasis represent a final common pathway for many disease processes.
- Prevalence worldwide is unknown.
- Three morphologic types.
  1. Cylindrical or tubular
  2. Vericose
  3. Saccular or cystic

Brochiectasis on Film - 1

ON CXR

• Loss of definition and increased number and size of bronchovascular markings.
  – Thought secondary to peribronchial fibrosis and secretions.
• Loss of lung volume.
• Honeycombing.
• Cystic spaces up to 2cm.
• Bronchography – introduced in 1922 – was the gold standard for diagnosis until HRCT.

A. H. is a 40 year old woman with mild bronchiectasis. Exam at BIDMC

- Moderate increase in lung markings, especially in the lingula which obscures the left heart border.
- No hilar or mediastinal lymphadenopathy.
• Cylindrical and cystic bronchiectasis on PA and bronchography.
• Without bronchography, the increased markings on the PA film would have been difficult to interpret.
Brochiectasis on Film – 1.3

- D.R. is a 64 year old man with bronchiectasis.
- BIDMC exams

Courtesy of Dr. Phil Boiselle.
Brochiectasis on Film – 1.4

- S.M. is a 76 year old woman with bibasilar bronchiectasis in the setting of a hiatal hernia.
- Possibly the result of chronic aspiration.
- BIDMC Exam
Brochiectasis on Film – Diagnosis

• HRCT is the best modality for assessing bronchiectasis.

**Rule of Thumb**

- Most reliable radiologic finding for cylindrical bronchiectasis is visualization of bronchi within 1 cm of pleura or visualization of bronchi abutting the mediastinal pleura.
- Lack of bronchial tapering and increased bronchoarterial ratios can help, but they occur in 10% to 20% of healthy subjects.
Bronchus < 1cm from pleura

Patient A.H. is a 40 year old woman with bronchiectasis of unclear etiology.

Note also that abnormal bronchi do not taper proximal to distal.
Bronchus / Pulmonary Artery Ratio

Patient A. H. age 40
Bronchus at this level = 4.9 mm
Pulmonary Artery Branch = 3.1 mm
Ratio = 1.5
Exam at BIDMC

Pt. T. C. age 39 with a normal chest CT
Bronchus at this level = 2.9 mm
Pulmonary Artery Branch = 4.2 mm
Ratio = 0.69
Exam at BIDMC
Bronchiectasis on HRCT: Resolution matters.

- Conventional CT with 8-10mm collimation showed sensitivity of 60% to 80% and a specificity of 86% to 100%.
- HRCT with 1.5-mm collimation at 10-mm intervals improved sensitivity to a range of 96% to 98% with a specificity of 93% to 99%.
- With the use of 4-mm collimation at 5-mm intervals, CT scanning was 100% sensitive for the cystic and varicose types and 94% sensitive for the cylindrical variety.

Fake Outs

- Artifacts from respiratory and cardiac motion.
- Inappropriate collimation and electronic windowing.
- Diffuse lung diseases such as pulmonary histiocytosis X, lymphangioleiomyomatosis, cystic changes in patients with AIDS and P. carinii pneumonia, and cystic metastases.
- Look for cyst next to an artery. This favors bronchiectasis over a cystic metastasis.
DDx of Bronchiectasis

Aspergillus as part of allergic bronchopulmonary aspergillosis can contribute to bronchial destruction.

Kartagener’s Syndrome – look for triad of situs abnormalities, nasal sinusitis, and bronchiectasis.

CF is a common cause.

In RA clinics, 1-3% of patients have clinical bronchiectasis. HRCT reveals 30% of RA patients with lung involvement.

NEJM, 346: 18, pgs. 1383-1393. May 2, 2002. Table 1 from page 1384.
Segmental Anatomy

Respiratory bronchiole

Lymphatics and pulmonary veins

Grey’s Anatomy, Figs 975 and 976, from http://www.bartleby.com/107
Emphysema

- Up to 30% of the lung can be involved before symptoms occur.
- 66 of adults have emphysema at autopsy.
- Diagnosis on CR from 65-80%.
- CT is more sensitive for diagnosis that CR or PFTs, but consistently underestimates when compared to pathology. CR can see emphysema before it becomes symptomatic.
- 3 types, in reference to the secondary lobule.
  - Centrilobular or Centriacinar.
  - Panlobular or Panacinar.
  - Paraseptal or Distal Lobular or Subpleural.
- Paracatricial emphysema also exists in the setting of pulmonary fibrosis, but this is a different diagnosis. Dilation of acini from scarring.
- Emphysema can be either focal or diffuse within the lung.

Radiologic Criteria for Emphysema

Criteria for chest radiographic diagnosis of emphysema include two or more of the following:

1. Depression and **flattening of the diaphragm** on the posteroanterior roentgenogram with blunting of costophrenic angles. The actual level of the diaphragm is not as significant as the contour. (This can be determined from a straight line connecting the costophrenic junction to the vertebrophrenic junction on each side; if the highest level of the contour is less than 1.5 cm above this line, the diaphragm can be recorded as flat.)

2. **Irregular radiolucency** of the lung, caused by irregularity in distribution of the emphysematous tissue destruction

3. Abnormal **retrosternal radiolucency**, as seen on lateral view, **measuring 2.5 cm or more** from the sternum to the most anterior margin of the ascending aorta

4. Flattening or even concavity of the diaphragm contour on the lateral chest radiograph, as determined by the presence of a **sternodiaphragmatic angle of 90° or larger**.

Emphysema in Radiology

- Decreased vascular markings suggests emphysema.
  - When combined with hyperinflation, specificity of diagnosis increases.
- Saber-sheath Trachea.
  - Sagital diameter or trachea is larger than coronal diameter.
  - Sagital / coronal ratio of 2:1 to diagnose the finding.
    Measured 1cm above the aortic arch.
  - 95 percent of patients with saber-sheath trachea have clinical or physiologic COPD.
  - Contrast this with 18 percent of controls (normal trachea) in the study population.
- Automated density mask programs assessing HRCT images for emphysema and comparing inspiration / expiration films are currently being researched as a method to quantify emphysematous changes.
- This is not in clinical practice, but may replace PFTs for quantification of all forms of COPD.

Examples

- Patient P. J. is a 65 year old man with emphysema, DM, neuropathy, and HTN.
- Exam at BIDMC

- Rule of thumb: sternodiaphragmatic angle < 90% suggests COPD.
Example

• What’s Abnormal?

Patient D.V., a 61 year old woman with emphysema. Exam

Ignore this for the moment.
Examples

What abnormalities do you see?

Increased Retrosternal Radiolucency. 3.6 cm.

Flattened Diaphragm

Patient D.V., a 61 year old woman with emphysema. Exam
Saber-sheath Trachea

Normal

Saber-sheath trachea

http://www.radiology.vcu.edu/2002%2009%2020%20cotw.htm
Centrilobular Emphysema

- Paradigm = SMOKING.
- Smoking raises alpha1-antitrypsin levels by 20 percent.
- Other toxic exposures may produce this pattern.
- Tends to effect the upper and posterior portions of the lung, sparing the lower portions.

Normal bronchial anatomy.  

Centrilobular Emphysema

Diagrams from RCoNA 36:1, 1998 pg. 16.
J.C., a 71 year-old Smoker with Emphysema

Patient has bilateral pleural effusions and bibasilar consolidation, suspicious for pneumonia. For emphysema in a smoker, our attention is to the apices.

Compliments of Dr. Chad Brecher, Chief Resident BIDMC Radiology.
CT with Centrilobular Emphysema

- J.C., age 71.
- BIDMC exam

Courtesy of Dr. Chad Brecher, Chief Resident BIDMC Radiology.
CT with Centrilobular Emphysema

- J.C., age 71.
- Worse at the apices.
- BIDMC exam

Courtesy of Dr. Chad Brecher, Chief Resident BIDMC Radiology.
Bullous Emphysema on HRCT

- Peripheral Bullae from centrilobular emphysema.
- Arrows represent preserved lung tissue and vessels.

Image from RCoNA 36:1, 1998 pg. 45, figure 14.
Panacinar Emphysema

- **Paradigm** = \( \alpha_1 \)-antitrypsin deficiency.
- Tends to effect lower lung > upper lung.
- Can be focal – behind an obstruction or congenital bronchial abnormality – or diffuse.

Diagram from RCoNA 36:1, 1998 pg. 16.

Photograph: cut surface of inflation-fixed lung.

Panacinar Emphysema due to alpha₁-antitrypsin deficiency

- J.C. is a 51 year old man with alpha₁-antitrypsin deficiency and severe emphysema.
- BIDMC Exam

Courtesy of Dr. Phil Boiselle.
Panacinar Emphysema on CT

- Pt. J.C. at age 51.
- Extensive emphysema at the apices.
- BIDMC exam

Courtesy of Dr. Phil Boiselle.
Panacinar Emphysema on CT

- Pt. J.C. at age 51.
- Even more extensive emphysema at the bases.
- BIDMC exam

Courtesy of Dr. Phil Boiselle.
Paraseptal Emphysema

• Emphysema along fibrous intralobular septa.
• Remainder of the lung is spared.
  – Usually no airflow compromise.
• Apical bullae can give rise to spontaneous pneumothorax.
Conclusions – Rules of Thumb

- **General**
  - Look for hyperinflation.
  - Explain all bullae.
  - Greater than expected lucency on PA chest radiograph, especially if focal or patchy should make one suspicious for COPD.

- **Bronchiectasis**
  - Bronchi visible less than 1cm from the periphery or abutting the mediastinum.
  - Increased bronchi / vascular ratio.

- **Emphysema**
  - Retrosternal radiolucency of greater than 2.5 cm.
  - Flattening or concavity of the diaphragm on the lateral chest radiograph: sternodiaphragmatic angle of 90° or larger.
References


- **Diagnosis for Case of the Week - September 20, 2002.** Virginia Commonwealth University Medical School. [http://www.radiology.vcu.edu/2002%2009%2020%20cotw.htm](http://www.radiology.vcu.edu/2002%2009%2020%20cotw.htm)
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