Obstructive Pulmonary Physiology
From the Imaging Perspective:
Balloons, Airway Inflammation or Dynamic Collapse
Marc V. Gosselin, MD
Vision Radiology
OHSU School of Medicine
Disclosures

- Lecture for Genentech on Interstitial lung disease imaging for Education only
- No drug promotion or research involvement
Lecture Objectives

- Introduce the differential of ‘COPD’
- Use of imaging to demonstrate the underlying pathology and help explain the clinical manifestation
- Clinical ‘Red Flags’ to alert the possible presence of other common, but often not clinically diagnosed cause of ‘COPD’

“Where all think alike, no one thinks very much”  Walter Lippmann
68 yo female with Worsening dyspnea over 12 months: 3 “COPD” admissions
Dyspnea: Started 8 Years Ago - Diagnosed with COPD/Emphysema, then lost Insurance coverage.
CAUTION

THIS SIGN HAS
SHARP EDGES

DO NOT TOUCH THE EDGES OF THIS SIGN

ALSO, THE BRIDGE IS OUT AHEAD
Normal Thin Section CT: Cardiac Motion
Normal Inspiration and Expiration
Chronic obstructive pulmonary disease (COPD) is a general term lumping emphysema, chronic bronchitis and asthma together.

COPD leads to reflexive treatment algorithms.

Disadvantages of using the term COPD:

- *Other obstructive conditions* are often over-looked.
- Pathologic and physiologic mechanisms of these diseases are different.
- Prognosis and treatment are disease specific.
White Zinfandel is NOT a wine!
Algorithmic Medicine

CAUTION
THIS MACHINE HAS NO BRAIN
USE YOUR OWN
Misconceptions about ‘COPD’ are very common:

- ‘Hyperinflation of lungs with smoking history means emphysema’
  (Pulmonologist)

- ‘Lungs that extend below 10th ribs is hyper inflated and represents COPD’
  ((Pulmonologist & Radiologist))

- ‘Emphysema is not diagnosed with imaging, it is a PFT diagnosis!’
  (Pulmonologist)
Misconceptions about ‘COPD’ are often taught with confidence:

- ‘Patient has emphysema, she was exposed to second hand smoke’ The response by a pulmonologist when I mentioned the patient likely has another cause for their obstructive lung disease given her recurrent admissions and not improving on treatment.

- ‘Hyperinflated lungs consistent with Emphysema’ – Radiology report and agreement by physician in a patient without any smoking history. Lost their insurance ‘For lying about smoking’

“We can be Absolutely Certain Only about Things We Do Not Understand.” Eric Hoffer
“The Greatest Obstacle to Discovery is not Ignorance, but the Illusion of Knowledge.”

Daniel J. Boorstin
35 yo non-smoking female with persistent dyspnea & some wheezing for 2 years – Clinical Diagnosis: ‘Poorly Responsive Asthma’
“COPD”: What You Should Be Considering

- 6 different pathologies can manifest with severe obstructive disease:
  - Emphysema (‘Balloons’)
  - Chronic Bronchitis
  - Asthma
  - Tracheobronchomomalacia (‘Dynamic’)
  - Constrictive Bronchiolitis (‘Balloons’)
  - Bronchiectasis (via Constrictive bronchiolitis)

The persistence or recurrence of symptoms should alert you that a diagnosis is being missed.
Obstructive Pulmonary Disease

- **Inflammatory**: Chronic bronchitis (Hypoxic), bronchiectasis and asthma (post viral or antigenic) (Shunt-like)

- **Balloons**: Space occupying diseases: (Increase in ‘Dead Space’) Emphysema and Constrictive bronchiolitis

- **Dynamic collapse**: Tracheobronchomalacia and/or Dynamic redundant posterior wall collapse (>70%)
What is the V/Q abnormality with Shunt Physiology?

- Persistent perfusion with decreased or absent ventilation = Shunt
- This induces hypoxia

**Chronic Bronchitis** is an example - Hence the term ‘Blue Bloater’

Also why **Pulmonary Hypertension** (Chronic Hypoxia induced) occurs so commonly with Chronic Bronchitis
What is Dead Space Physiology?

- Persistent ventilation with decreased/absent perfusion
- No to mild hypoxia
- Pulmonary embolus is a perfect example of a Dead Space Physiology
- Emphysema (‘Pink Puffer’), Constrictive Bronchiolitis and Tracheobronchomalacia often maintain a relatively balanced V/Q ratio at the alveolar levels

Radiographic Signs of Hyperinflation

- **Flat diaphragm** *(Increased trapped RV)*
- Sterno-diaphragmatic angle approaches **90 degrees** on lateral
- Increased width of retrosternal air space
- Increased AP diameter

**Note:** Lungs extending below 10th rib is **NOT** a reliable criteria – ‘People are like Snowflakes’
Is There Hyperinflation?
Emphysema: Radiographic Imaging

- Vascular attenuation and depletion with increasing branch angles approaching 90 degrees
- Hilum are ‘pushed’ inferior and medial
- Vascular crowding along the medial and lower lobes
- Check pulmonary artery size if advanced (Pulmonary hypertension)
- Cachexia may be present (Reason?)
Radiograph Characteristic for Advanced Emphysema
Emphysema: CT Imaging

Different types such as Centrilobular (most common), Panlobular, Bullous and Paraseptal

No visible wall and has a central/peripheral ‘Dot’ representing the residual Central bronchovascular bundle

Cysts have no central/peripheral ‘Dot’ and often have walls
Hypothetical mechanism on how the expansion occurs when filled. It is *Non-dynamic*.
Peripheral Bullous Emphysema
Minimal *Dynamic Changes*: Increase in End-Tidal Residual Volume
When a lung with emphysema is removed at autopsy, the lung collapses, but not the emphysema.
Consolidation & Ground Glass looks heterogeneous with Emphysema
Why these ‘holes’ with edema or pneumonia?
Nothing gets in or out... like *Non-dynamic Balloons*
Increase in End-Tidal Residual Volume

What is The Surgical Therapy Called?
Why Cachexia?
Where all think alike, no one thinks very much.

Littermann
68 yo female with Worsening dyspnea over 12 months: 3 “COPD” admissions
68 year old female with Advanced Rheumatoid Arthritis:

Worsening dyspnea and hypoxia over 2 years with recurrent admissions for “COPD” exacerbations
Inspiration

Is There Emphysema?

Expiration

Is this RA-associated Constrictive Bronchiolitis?
Follicular Bronchiolitis AND Tracheobronchomalacia

How Well Does the ‘COPD’ Standard Therapy Work?
The patient states that Steroids did not seem to help with her breathing. Albuterol had no effect.

She did mention that the little plastic **FEV1 portable device** seemed to help the most. Blows into it against resistance = A form of PEEP. Much like breathing through her pursed lips.
Tracheobronchomalacia

- Collapsing (>70%) of the Trachea and/or Bronchi with global air trapping
- Cartilage weakness
- Excessive Dynamic Tracheal collapse (EDTC)
- Pursed lip breathing
- Vocal cord dysfunction
- Chronic cough, often ‘difficulty clearing secretions’, Dyspnea, Exercise intolerance, wheezing
Diagnosis: *Slowly Resolving Multifocal Pneumonia and “COPD”*

30 Pack Year Smoking History

More Generalized Lung/Lobar Obstruction…
Tracheobronchomalacia

- ‘Poorly responsive’ Asthma/COPD
- *Recurrent ‘COPD’ exacerbations* (Not treating the correct diagnosis)

**Associations:**
- Chronic Steroids (Autoimmune diseases)
- Constrictive Bronchiolitis → Tracheobronchomalacia
  (Often secondary to Chronic Steroids)
- Sleep Apnea
Inhaled corticosteroids – ‘ICS’

Effects of long-term ICS on airway remodeling

CTA Shortness of Breath (Pursed lip Breathing)
Incidence of Tracheobronchomalacia

Tracheobronchomalacia Incidence on ALL Pulmonary CTA’s is about 1 out of 10

Red Flag Indications: Shortness of Breath, Persistent cough, unable to clear secretions, ‘COPD’, Severe ‘Asthma’

Need expiratory imaging or Respiratory motion during exam

2 out of 10 with ‘COPD’ diagnosis
7 out of 10 with ‘Severe Asthma’ diagnosis

Hasegawa et al: AJR December 2003;181:1505–1509
CTA for Shortness of Breath: Tracheobronchomalacia is the problem – Improved quickly with BiPap

(Also: Patient complained could not cough up secretions)
“Education is the progression from a cocky ignorance to a miserable uncertainty.”

Mark Twain
Dyspnea: Started 8 Years Ago
Diagnosed with COPD/Emphysema & Lost Insurance

Is This Emphysema?
Is there Emphysema?

58 year old LDS women
Constrictive Bronchiolitis
(AKA: Bronchiolitis Obliterans)

Injury occurred after her Respiratory Infection 8 Years Ago
‘BO’ is Common But NOT commonly diagnosed!
41 year old female with persistent dyspnea, difficulty with exercise and weight loss over a 2 year period.

14 pack/year smoking history.
Dyspnea started in late 2017 after waking up in a house fire accident. Diagnosis?
Constrictive Bronchiolitis

**Pathology:** It is a *Permanent Scar* of the Respiratory or Terminal bronchioles

**Etiology:** Whatever induces *injury with necrosis* to the bronchial mucosa

**Common Causes:** Airway infections (Especially typical viral and mycoplasma), Bronchiectasis, Smoke inhalation, Drug toxicity, Transplant rejection & Autoimmune diseases

Mosaic Lung Attenuation: *Look at the vessels* - Patchy Perfusion $\rightarrow$ Small Airways Disease vs. Pulmonary Hypertension
Constrictive Bronchiolitis: Similar Physiology to Emphysema, Often with Less Hypoxia
Constrictive Bronchiolitis

**Symptoms:** *Persistent* Dyspnea/cough not responsive to steroids/albuterol

*Not episodic* (Asthma)

**Clue:** OFTEN a patient can tell you *WHEN* their breathing difficulties began

**Example:** *Post RSV infection 2 yo* – ‘Increase risk of Asthma, but often grows out of it’ – Is it Asthma? Why do they improve with age?

What if the child was a *15 yo* with mycoplasma?
Constrictive Bronchiolitis

**Imaging:** *Patchy areas of air trapping on expiration thin section CT imaging*

Contrast with Tracheobronchomalacia which has more *global areas of air trapping* since the obstruction is more central.

**Confounding:** Bronchomalacia involving the more segmental bronchi can be more difficult to distinguish.

**Note:** Constrictive Bronchiolitis and Tracheobronchomalacia *can coexist* (Especially if on Chronic Steroids for misdiagnosed Constrictive Bronchiolitis)
Right Transplanted Lung: Constrictive Bronchiolitis (Left Native Lung: Emphysema)
Bronchiectasis with air-trapping is often secondary to Constrictive bronchiolitis
Cystic Fibrosis: 40 yo with progressive worsening dyspnea
Cystic Fibrosis and Constrictive Bronchiolitis

- Constrictive Bronchiolitis is an expected complication of CF patients.
- Evolving as a common cause of mortality.
- Try to mention its presence and/or extent in your reports.
- Look for it on all other chronic airway diseases, especially with bronchiectasis.

Harris et al. Constrictive Bronchiolitis in Cystic Fibrosis Adolescent with refractory pulmonary decline. Ann Am thorac Soc. 2016 Dec; 13(12) 2174-2183
42 yo Male With Recurrent “Bronchitis”

Localized versus Widespread Distribution of Bronchiectasis
75 yo Female: Chronic Cough

Diagnosis?

Why are the vessels attenuated within areas of bronchiectasis?
“Signet” or
“Solitaire” Ring Sign

Or A
Cabochoon
Ring?
Clinical ‘Red Flags’

- Persistence or Recurrence of symptoms & signs – i.e. *Multiple ‘COPD’ admissions*
- Patient can identify time period or event when the breathing difficulties began
- Breathing through pursed lips or a concurrent diagnosis of “vocal cord dysfunction”
- Do not fully respond to steroid/albuterol therapy
Truth pass through 3 stages: *First*, It is ridiculed. *Second*, It is violently opposed. *Third*, It is eventually accepted as being Self Evident.

Arthur Schopenhauer
Thank You – mgosselin@visionradiology.com
or Gosselin@OHSU.edu

When radiologists take a selfie
Question 1: When you see severe tracheobronchomalacia with global air-trapping in a patient with shortness of breath, what recommendation may be a useful?

A. More steroids would help

B. Antibiotics should be given

C. A trial of Bipap should be given

D. Bronchodilators are often useful

E. No suggestion since they know how to treat ‘COPD’
**Question 1:** When you see severe tracheobronchomalacia with global air-trapping in a patient with shortness of breath, *what recommendation may be a useful?*

**Answer is D. A trial of Bipap should be given**

The dynamic collapse of tracheobronchomalacia often responds quickly to positive pressure. A patient’s shortness of breath will often improve when this is the issue.

More steroids won’t help and will very likely have adverse consequences with tracheobronchomalacia. Best to try and wean them off all steroids. Antibiotics if infected only. Bronchodilators do not help with the collapse. The vast majority of doctors do not even know about tracheomalacia, inform them about it.
Question 2: Which process is an example of Shunt Physiology and often Hypoxic?

A. Chronic Bronchitis
B. Emphysema
C. Constrictive bronchiolitis
D. Pulmonary embolus
E. Tracheobronchomalacia
**Question 2:** Which process is an example of Shunt Physiology and often Hypoxic?

**Answer is A:** Chronic Bronchitis. 

*Persistent perfusion with altered/decreased ventilation = Shunt.* This induces hypoxia (Hence the term ‘Blue Bloater’)

- Pulmonary embolus is an example of a Dead Space Physiology: Persistent ventilation with decreased/absent perfusion (Not hypoxic)

- Emphysema, Tracheobronchomalacia and Constrictive Bronchiolitis often maintain the V/Q ratio at the alveolar levels
Question 3: What is a strong *clinical clue* that a patient’s Obstructive Pulmonary Physiology is from *Constrictive Bronchiolitis*?

- A. Long smoking history
- B. There is an identifiable point in time when the breathing difficulties developed
- C. Chronic steroid use
- D. Pursed lip breathing
- E. There are no good clinical clues, that is why there is imaging
Question 3: What is a strong clinical clue that a patient’s Obstructive Pulmonary Physiology is from Constrictive Bronchiolitis?

Answer is B - There is an identifiable point in time when the breathing difficulties developed.

This clue in the history is a strong predictor of constrictive bronchiolitis, an injury occurred with resultant scarring down of large areas of bronchioles. Pursed lip breathing favors a dynamic collapse of the central airways. Smoking favors emphysema/chronic bronchitis. Chronic steroids are associated with Constrictive Bronchiolitis, because it is misdiagnosed as ‘Resistant Asthma’ or ‘COPD’.
Question 4: Which Imaging finding, in a patient with an obstructive pulmonary process, suggests it may NOT be due to Emphysema?

A. CT shows widespread < 10mm lucencies with a central/peripheral ‘Dot’
B. Radiograph shows the Hilum displaced inferiorly and medially
C. Radiographic vascular crowding medially and lower lobes
D. Uniform Pulmonary Vessels showing most branch angles of <50 degrees throughout the lungs
E. Flattening of the diaphragm
Question 4: Which Imaging finding, in a patient with an obstructive pulmonary process, suggests it may NOT be due to Emphysema?

Answer is D – Uniform Pulmonary Vessels showing most branch angles < 50 degrees throughout the lungs

Vascular attenuation & depletion causes widening branch angles, especially in upper lobes. This is associated with Emphysema much more than the other etiologies.

Question 5: Incidence of Tracheobronchomalacia on All CTA’s for PE is approximately...

A. 1 out of 200
B. 1 out of 100
C. 1 out of 50
D. 1 out of 10
E. 1 out of 2
Question 5: Incidence of Tracheobronchomalacia on All CTA’s for PE is approximately...

Answer D: 1 out of 10

There is not a lot of data on the true incidence, but important to recognize that it is a common finding, especially with SOB.

Make it a routine part of your CTA evaluation (Much more likely to find this than a PE!)

Red Flags: SHORTNESS OF BREATH, persistent cough, unable to clear secretions, pursed lip breathing, ‘COPD’, Persistent or Severe ‘Asthma’

Hasegawa et al: AJR December 2003;181:1505–1509
Enjoy Some Fine Non-White Zinfandel Wine Tonight!