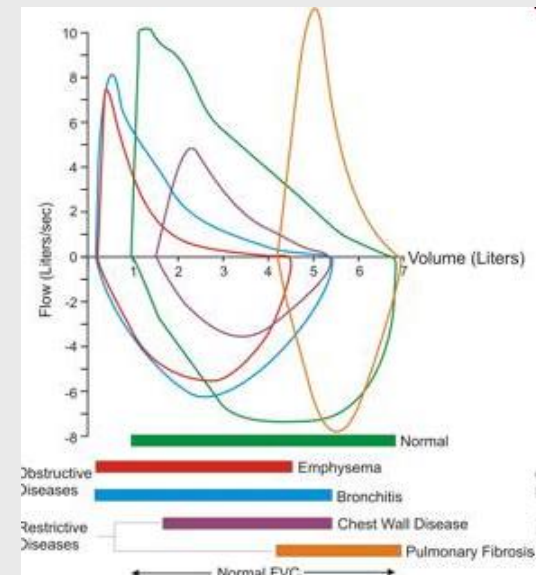


Board Review of Pulmonary Medicine

**A case-based study of pulmonary concepts --
pulmonary function and clinical correlation**

Rendell Ashton, MD, FACP, FCCP
**Cleveland Clinic Dept of Pulmonary
and Critical Care**



Case-based study of pulmonary concepts -- pulmonary function and clinical correlation

- **Spirometry (with flow-volume loop)**
- **Lung volume**
- **Diffusing capacity**

A. Idiopathic pulmonary fibrosis (IPF)

B. Asthma

C. Tracheal stenosis due to prolonged intubation

D. Alpha 1-antitrypsin deficiency

E. Relapsing polychondritis

Spirometry

(“measurement of breathing”)

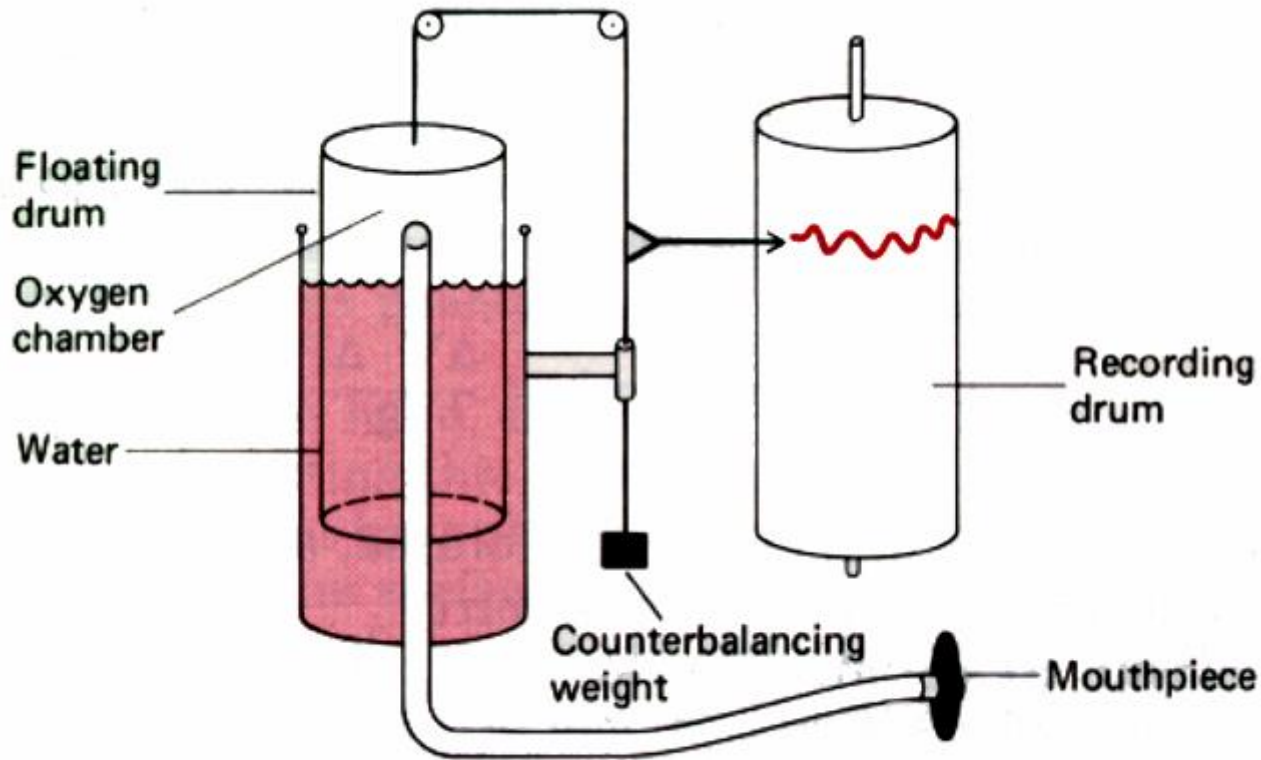
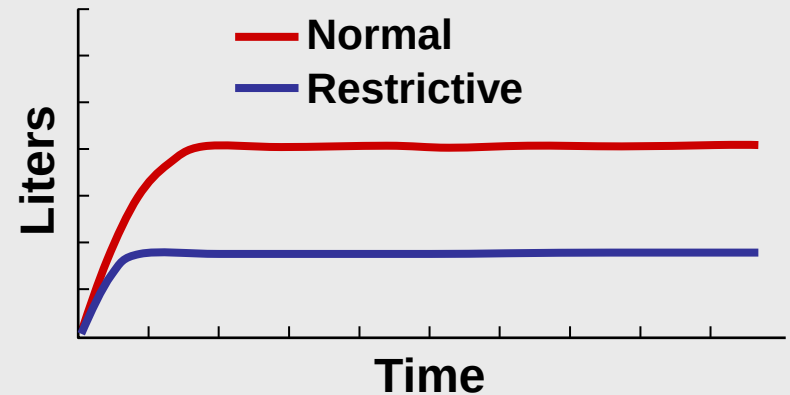
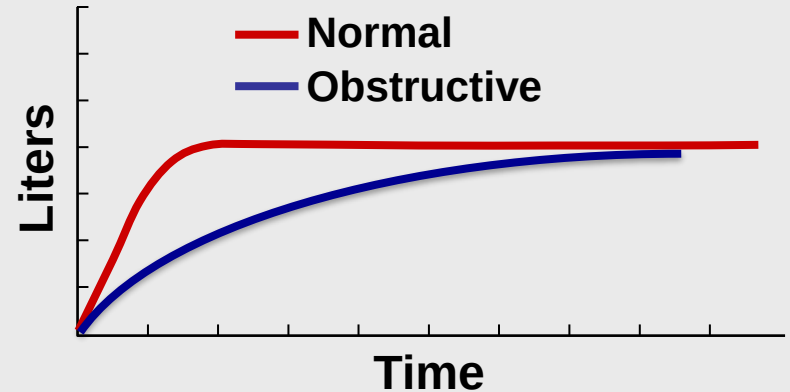


Figure 39–4. A spirometer.

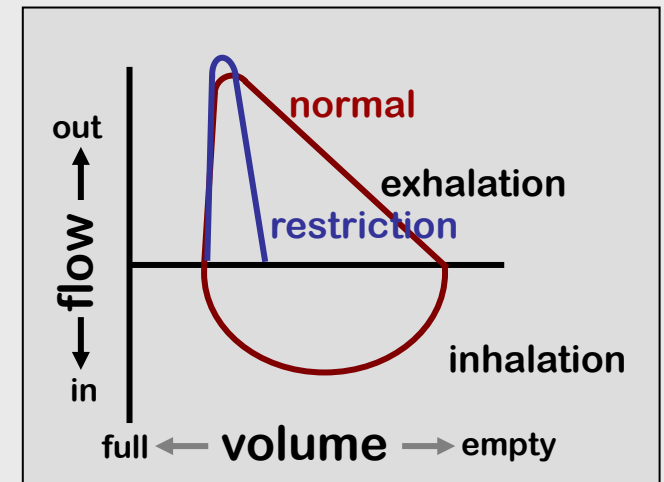
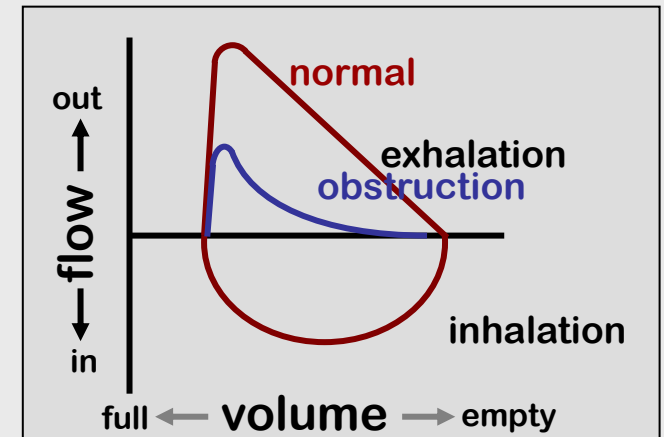
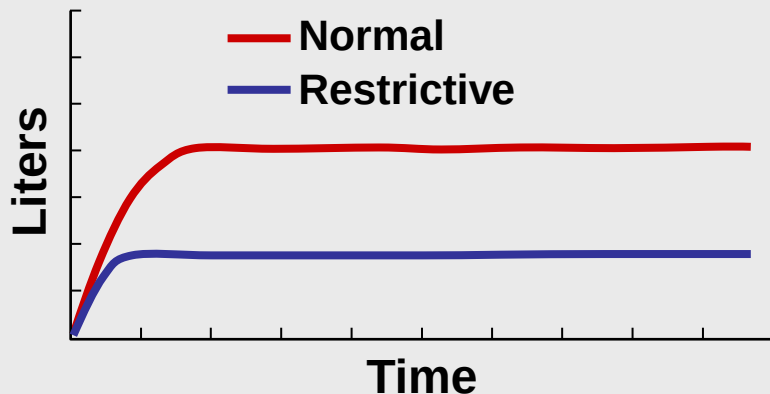
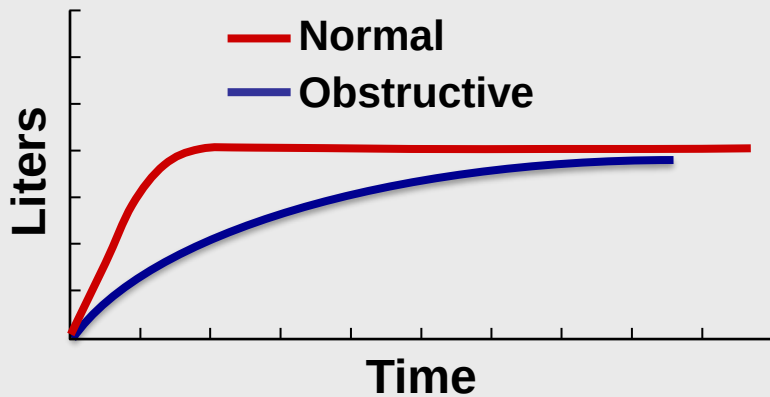
Spirometry

(“measurement of breathing”)

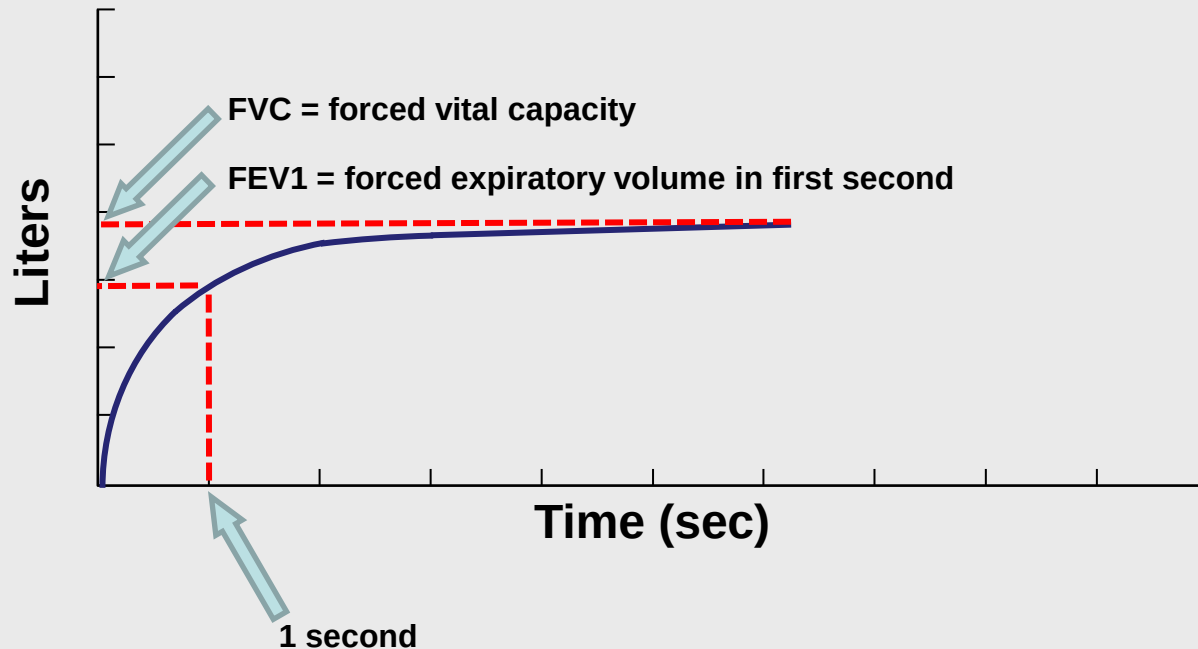


Spirometry

(“measurement of breathing”)



Spirometry: Interpretation



$FEV1/FVC < 5^{\text{th}}$ percentile of predicted value $\rightarrow$ definition of obstruction

TLC (total lung capacity) $< 5^{\text{th}}$ percentile predicted $\rightarrow$ definition of restriction

- Low vital capacity suggests but does not diagnose restriction!

Mixed pattern = both $FEV1/FVC$ and TLC are below 5^{th} percentile predicted

Eur Respir J 2005; 26: 948-968

Severity in PFT's

- **2005 Guidelines**

Severity of Lung Function Impairment

- Using FEV₁ (includes obstruction or restriction):
 - Mild = FEV₁ > 70% predicted
 - Mod = 60-69% predicted
 - Mod-Severe = 50-59% predicted
 - Severe = 35-49% predicted
 - Very severe = < 35% predicted

- **2021 Guidelines**

Severity of Lung Function Impairment

- For all measures use z-score:
 - Mild = -1.65 to -2.5
 - Mod = -2.51 to -4.0
 - Severe = > -4

**Severity ratings are useful mostly for research and epidemiology
– not as useful clinically.**

Eur Respir J 2005; 26: 948-968

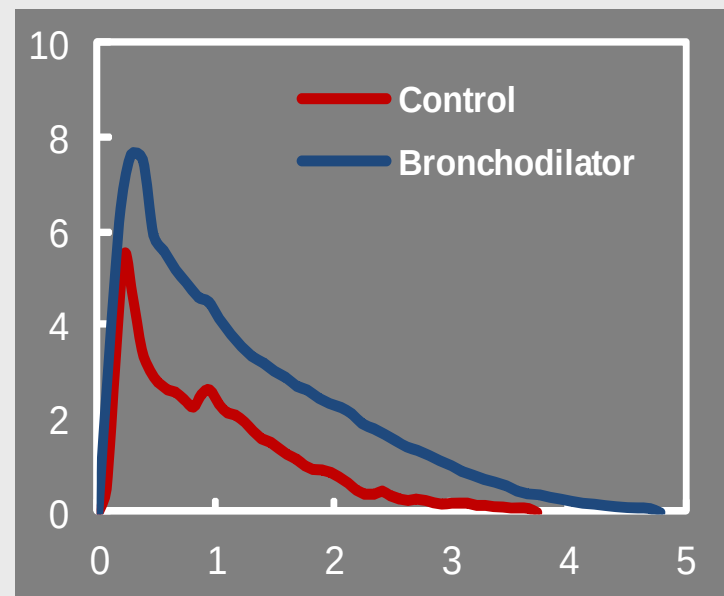
Eur Respir J 2022; 60: 2101499

Spirometry: Interpretation

- **Bronchodilator response**
 - FEV1 or FVC increases $\geq$ **10% of predicted value** = positive bronchodilator response
 - “The absence of bronchodilator response in the laboratory does not preclude a clinical response to bronchodilator therapy”

63-year-old man with mild shortness of breath, persistent cough & wheeze; former smoker

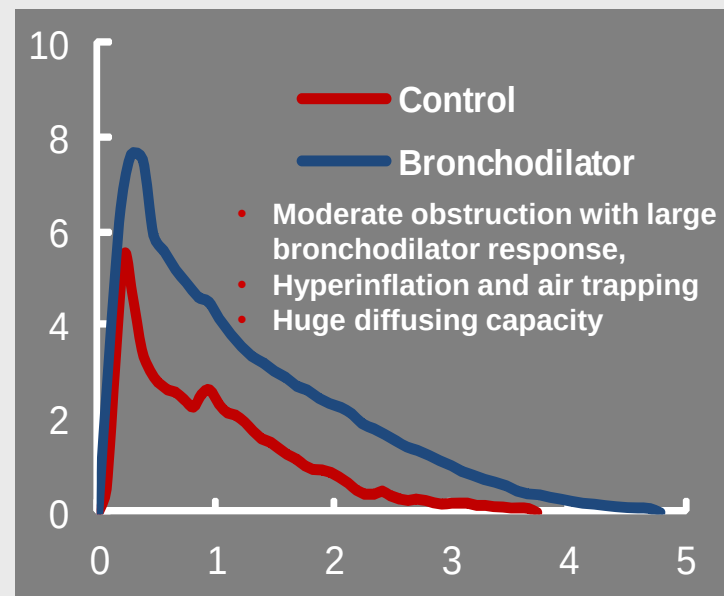
	(L)	(% of predicted)		
TLC	9.07	127%		
RV	4.62	216%		
RV/TLC	50.9	170%		
FVC	3.74	74%	4.79	+28%
FEV ₁	1.93	50%	2.81	+46%
FEV ₁ /FVC	51.6			
DLCO	50	176%		
SPO ₂	95% → 93% (w/ exercise)			



- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

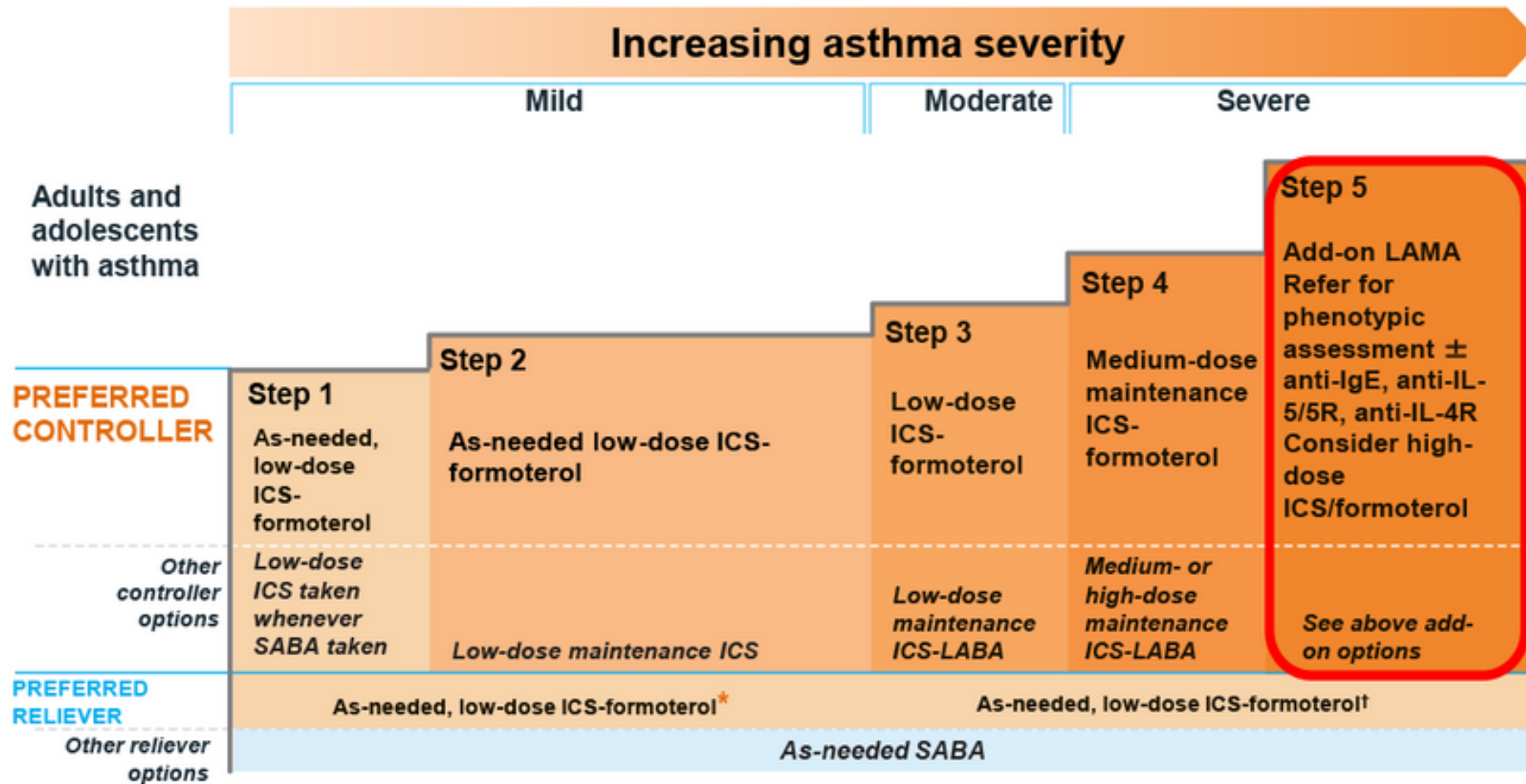
63-year-old man with mild shortness of breath, persistent cough & wheeze; former smoker

	(L)	(% of predicted)		
TLC	9.07	127%		
RV	4.62	216%		
RV/TLC	50.9	170%		
FVC	3.74	74%	4.79	+28%
FEV ₁	1.93	50%	2.81	+46%
FEV ₁ /FVC	51.6			
DLCO	50	176%		
SPO ₂	95% → 93%	(w/ exercise)		



- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

GINA 2021: Stepwise Treatment Approach



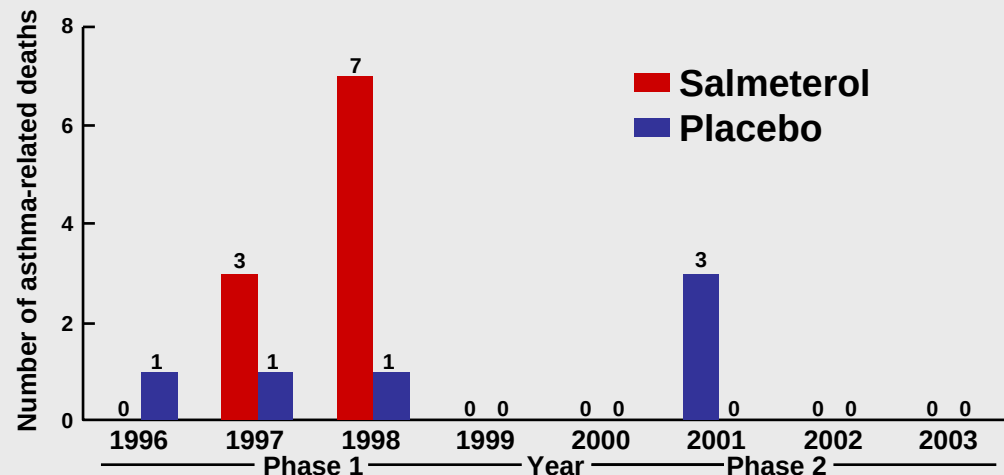
FDA = US Food and Drug Administration; ICS = inhaled corticosteroid; Ig = immunoglobulin; IL = interleukin; LABA = long-acting β 2-agonist; LTRA = leukotriene receptor antagonist; OCS = oral corticosteroid; SABA = short-acting β 2-agonist.

Adapted from GINA. Global Strategy for Asthma Management and Prevention. Updated 2021
(<https://ginasthma.org/wp-content/uploads/2021/05/GINA-Main-Report-2021-V2-WMS.pdf>). Accessed 7/25/21.

Long-acting Beta Agonists (LABA's) in Asthma

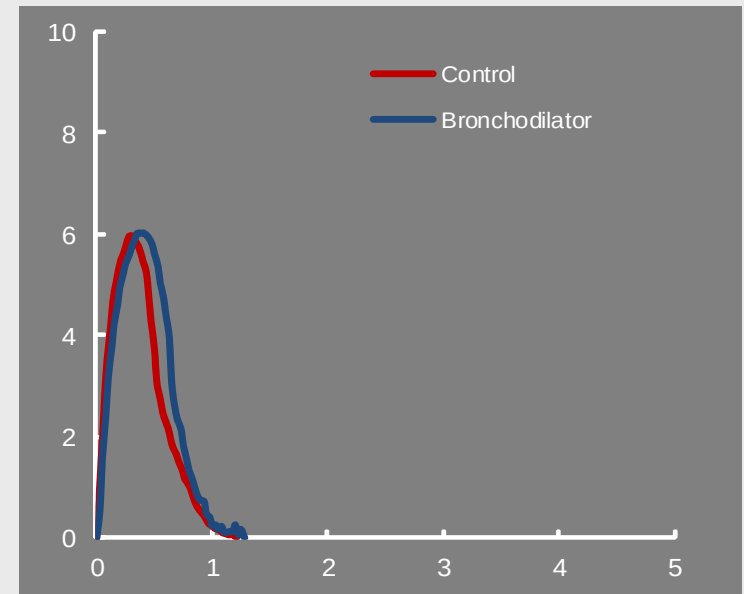
- SMART trial suggested increased mortality with use of LABA's
 - Negative trial for primary endpoint (respiratory deaths)
 - Uncontrolled for inhaled steroid use (although randomized)
 - Mortality higher in African American patients (posthoc subgroup)
- Consensus
 - LABA's still recommended but only when combined with inhaled steroids
 - Only use when necessary to control asthma symptoms

Occurrence of Asthma-related Deaths by Phase and Study Year



70-year-old woman with mild shortness of breath; only smoked 7 years

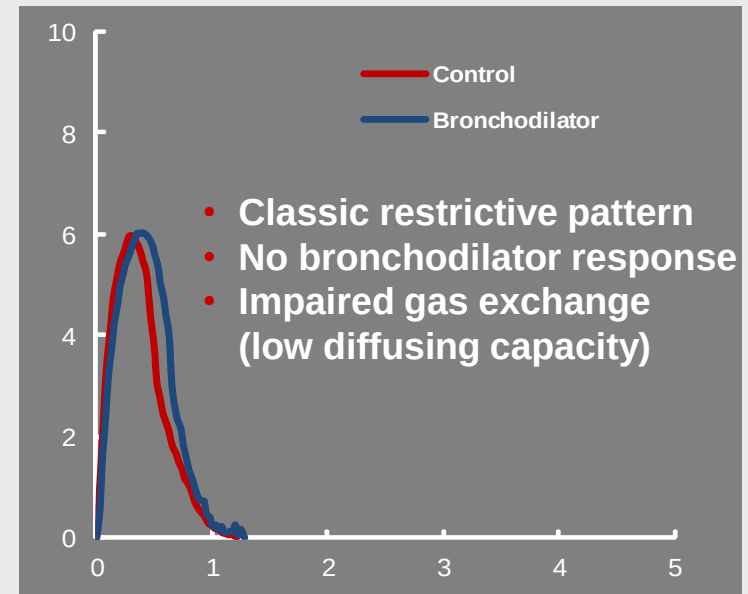
TLC	2.28	49%		
RV	0.86	43%		
RV/TLC	37.7	87%		
FVC	1.21	46%	1.28	+6%
FEV ₁	1.06	50%	1.10	+4%
FEV ₁ /FVC	87.5			
MVV	64	75%		
DLCO	9.0	46%		
SPO ₂	96%→86% (w/ exercise)			



- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

70-year-old woman with mild shortness of breath; only smoked 7 years

TLC	2.28	49%		
RV	0.86	43%		
RV/TLC	37.7	87%		
FVC	1.21	46%	1.28	+6%
FEV ₁	1.06	50%	1.10	+4%
FEV ₁ /FVC	87.5			
MVV	64	75%		
DLCO	9.0	46%		
SPO ₂	96%→86% (w/ exercise)			

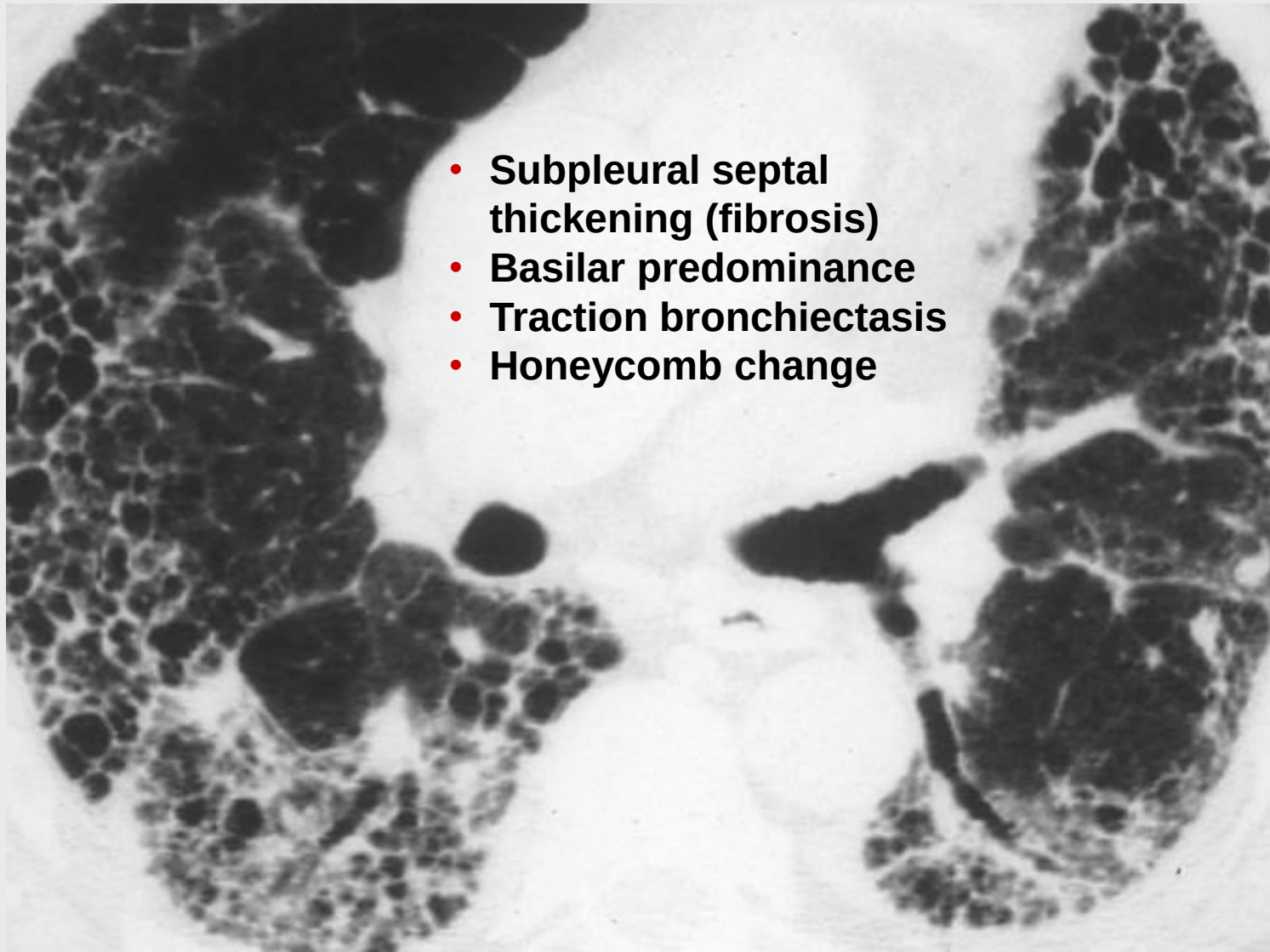


- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

Idiopathic Pulmonary Fibrosis: Clinical Presentation

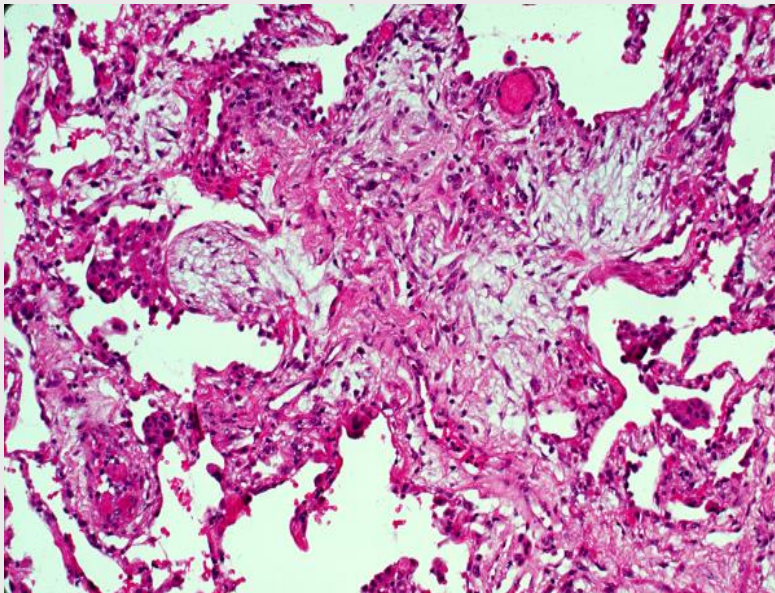
- **Prototypical “interstitial lung disease”**
- **Middle-aged to elderly patients**
- **Slowly progressive dyspnea and cough**
- **Bibasilar “Velcro” crackles; $\pm$ clubbing**
- **PFT: restrictive with decreased diffusing capacity**
- **Median survival: 3 yrs**

IPF on CT Imaging

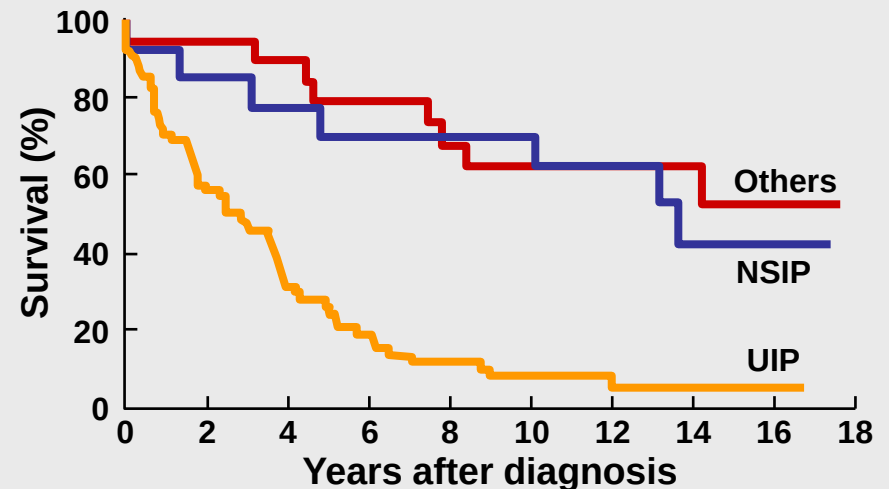


Usual Interstitial Pneumonia

- Heterogeneous with alternating zones of normal lung, active fibrosis (fibroblastic foci), and honeycomb change
- Most pronounced in the subpleural regions



- Idiopathic (IPF)
- Known cause or underlying disease:
 - Connective tissue diseases
 - Chronic hypersensitivity pneumonitis
 - Asbestosis
 - Drugs (bleomycin, nitrofurantoin,...)
 - Other (radiation, aspiration, etc)



Poor Richard, 1733.

A N

Almanack

For the Year of Christ

1 7 3 3,

Being the First after LEAP YEAR:

<i>And makes since the Creation</i>	Years
By the Account of the Eastern Greeks	7241
By the Latin Church, when $\odot$ ent. γ	6932
By the Computation of <i>W. W.</i>	5742
By the Roman Chronology	5682
By the Jewish Rabbits	5494

Wherein is contained

The Lunations, Eclipses, Judgment of the Weather, Spring Tides, Planets Motions & mutual Aspects, Sun and Moon's Rising and Setting, Length of Days, Time of High Water, Fairs, Courts, and observable Days.

Fitted to the Latitude of Forty Degrees, and a Meridian of Five Hours West from London, but may without sensible Error, serve all the adjacent Places, even from Newfoundland to South-Carolina.

By RICHARD SAUNDERS, Philom.

PHILADELPHIA:

Printed and sold by B. FRANKLIN, at the New Printing-Office near the Market.

“He is the best
physician
who knows
the worthlessness
of the most
medicines

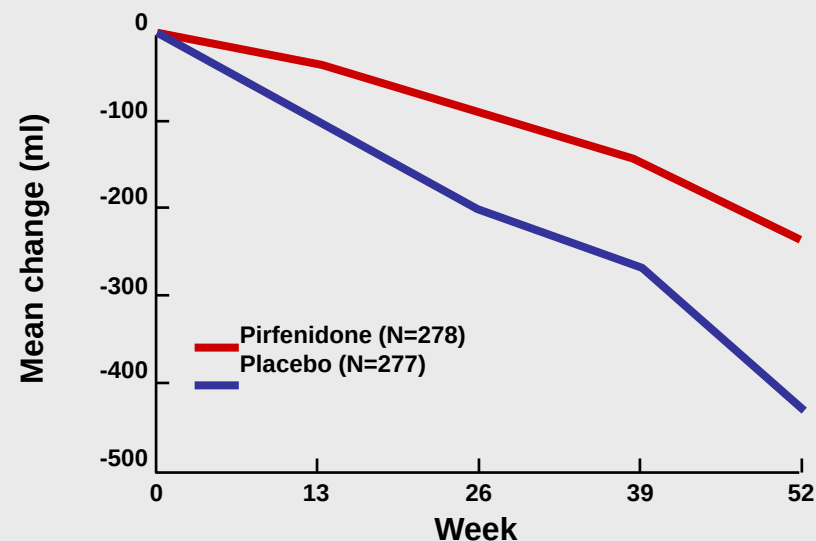
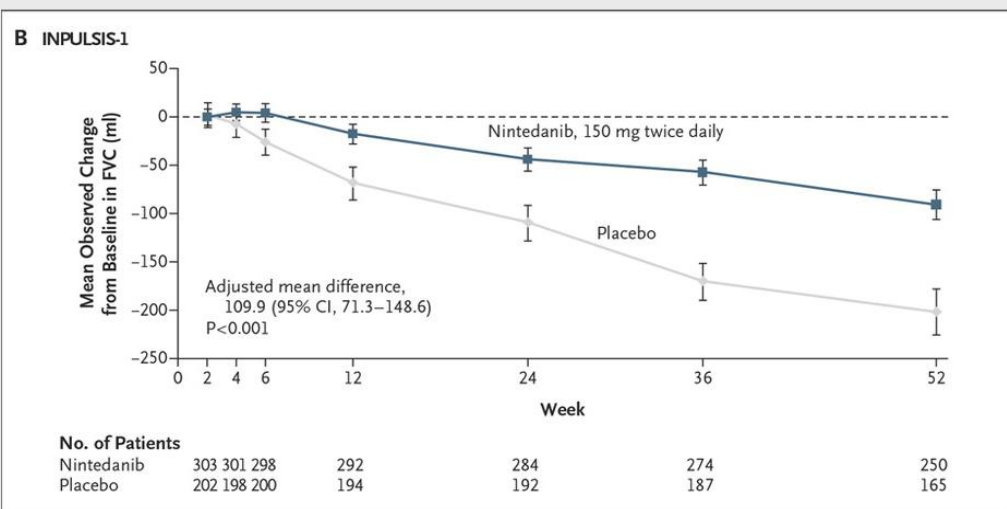
An authority on
treatment of IPF
(until 2014 . . .
And maybe still)

-- B. Franklin

Nintedanib

Pirfenidone

B. Change in FVC



King TE Jr et al. *N Engl J Med* 2014;370:2083-2092.



Richeldi L et al. *N Engl J Med* 2014;370:2071-2082.

Not all restriction is ILD . . .

1. Parenchymal restriction

- IPF, other ILD

2. Chest wall restriction

- Obesity
- Scoliosis
- Surgical or natural remodeling

3. Neuromuscular restriction

- ALS, GBS, etc.



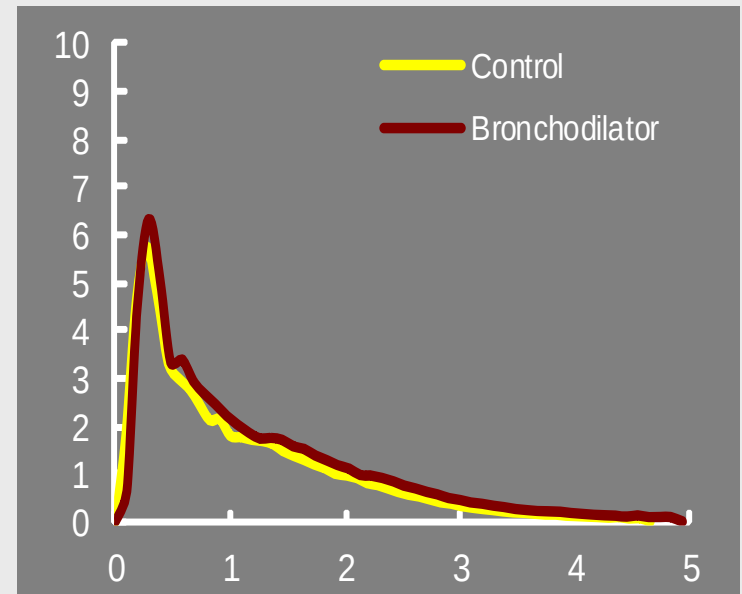
Usually normal diffusing capacity
...or normalizes with volume correction



37-year-old man with progressive shortness of breath; 10 pack-year smoking history

Ht: 177.2 Wt: 62.3 BMI: 19.9

TLC	9.85	145%		
RV	4.82	302%		
RV/TLC	48.9	208%		
FVC	4.65	90%	4.93	+6%
FEV ₁	1.93	46%	2.07	+7%
FEV1/FVC	41.6			
FEF25-75	0.5	13%		
DLCO	22.7	68%		
SPO ₂	97% → 96% (w/ exercise)			

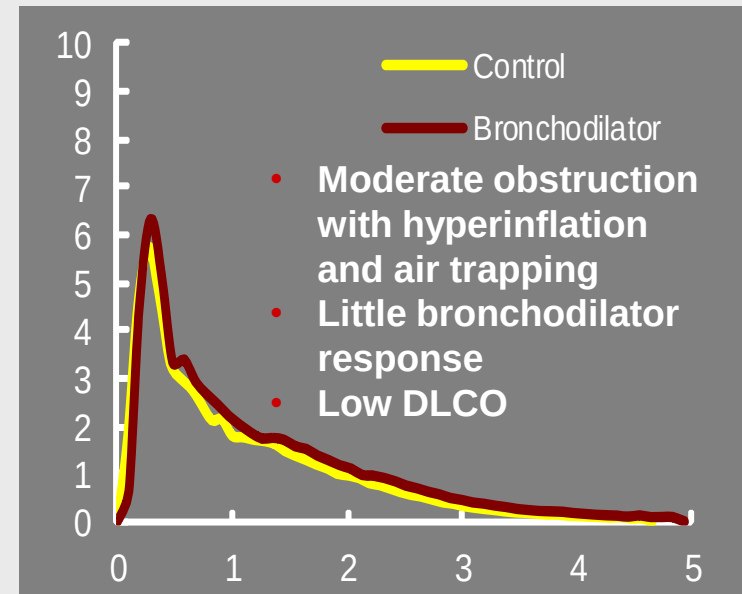


- A.** Idiopathic pulmonary fibrosis (IPF)
- B.** Asthma
- C.** Tracheal stenosis due to prolonged intubation
- D.** Alpha 1-antitrypsin deficiency
- E.** Relapsing polychondritis

37-year-old man with progressive shortness of breath; 10 pack-year smoking history

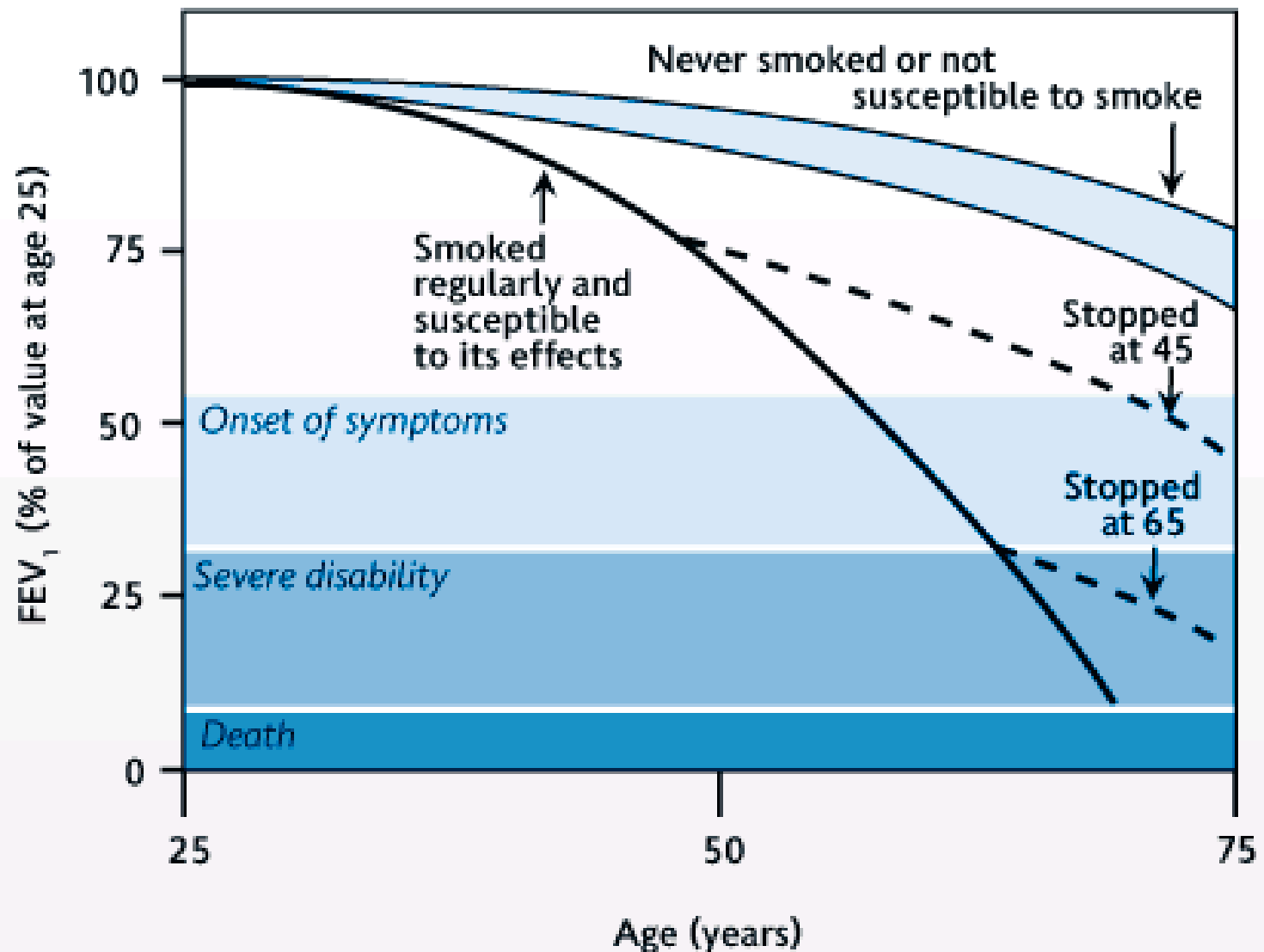
Ht: 177.2 Wt: 62.3 BMI: 19.9

TLC	9.85	145%		
RV	4.82	302%		
RV/TLC	48.9	208%		
FVC	4.65	90%	4.93	+6%
FEV ₁	1.93	46%	2.07	+7%
FEV1/FVC	41.6			
FEF25-75	0.5	13%		
DLCO	22.7	68%		
SPO ₂	97% → 96% (w/ exercise)			



- A. Idiopathic pulmonary fibrosis (IPF)
- B. Asthma
- C. Tracheal stenosis due to prolonged intubation
- D. Alpha 1-antitrypsin deficiency
- E. Relapsing polychondritis

COPD — Natural History



Spirometrically confirmed diagnosis

Assessment of airflow obstruction

Assessment of symptoms/risk of exacerbations

Post-bronchodilator
 $FEV_1/FVC < 0.7$

(We use $< LLN$)

Grade	FEV_1 (% pred)
GOLD 1	≥ 80
GOLD 2	50–79
GOLD 3	30–49
GOLD 4	< 30

Exacerbation history
(per year)

≥ 2 moderate exacerbations or
 ≥ 1 leading to hospitalization

0 or 1 moderate exacerbations
(not leading to hospitalization)

E

A

B

mMRC 0–1
CAT < 10

mMRC ≥ 2
CAT ≥ 10

Symptoms

goldcopd.org

Alvar Agustí et al. Eur Respir J 2023;61:2300239

Initial pharmacological treatment. mMRC: modified Medical Research Council Dyspnea Questionnaire; CAT: COPD Assessment Test; LAMA: long-acting anti-muscarinic antagonist; LABA: long-acting β 2 receptor agonist; ICS: inhaled corticosteroid; eos: eosinophils.

Initial pharmacological treatment

≥ 2 moderate exacerbations or ≥ 1 leading to hospitalization

Group E

LABA+LAMA[#]
consider LABA+LAMA+ICS[#] if blood eos ≥ 300

0 or 1 moderate exacerbations (not leading to hospital admission)

Group A

A bronchodilator
(LAMA or LABA)

Group B

LABA+LAMA[#]

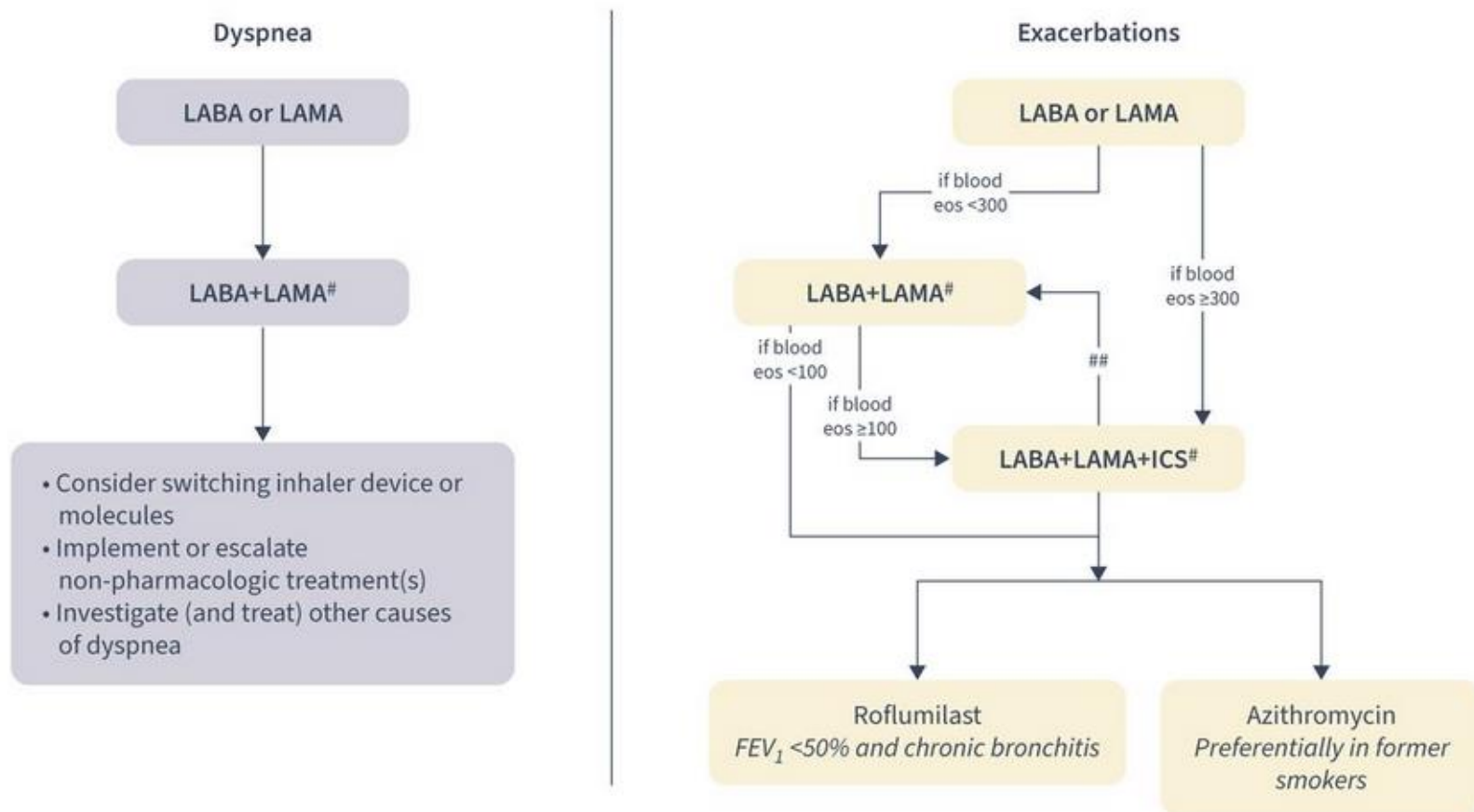
mMRC 0–1, CAT <10

mMRC ≥ 2 , CAT ≥ 10

[#]: single inhaler therapy may be more convenient and effective than multiple inhalers
Exacerbations refers to the number of exacerbations per year

Alvar Agustí et al. Eur Respir J 2023;61:2300239

- 1 If response to initial treatment is appropriate, maintain it
- 2 If not:
 - Check adherence, inhaler technique and possible interfering comorbidities
 - Consider the predominant treatable trait to target (dyspnea or exacerbations)
 - Use exacerbation pathway if both exacerbations and dyspnea need to be targeted
 - Place patient in box corresponding to current treatment and follow indications
 - Assess response, adjust and review
 - These recommendations do not depend on the ABE assessment at diagnosis



#: single inhaler therapy may be more convenient and effective than multiple inhalers

##: consider de-escalation of ICS if pneumonia or other considerable side-effects. In case of blood eos ≥ 300 cells· μL^{-1}

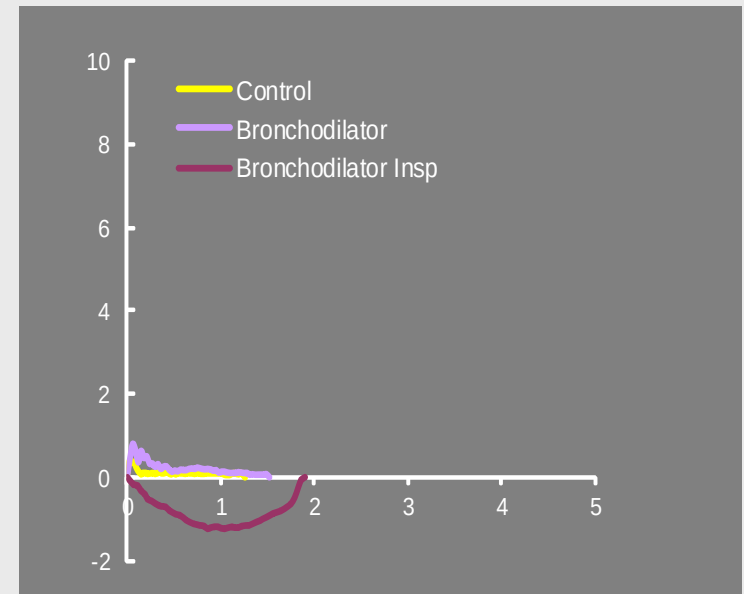
de-escalation is more likely to be associated with the development of exacerbations

Exacerbations refers to the number of exacerbations per year

64-year-old with severe dyspnea; former smoker of 25 pack-years, quit 4 months ago

Ht: 145.8 Wt: 37.1

TLC	5.76	145%		
RV	3.69	227%		
RV/TLC	64.0	157%		
FVC	1.26	54%	1.52	+20%
FEV ₁	0.16	8%	0.28	+72%
FEV ₁ /FVC	13.0			
FEFmax	0.6	13%		
FEF25-75	0.1	4%		
DLCO	12	64%		
VA	3.61	91%		
SPO ₂	96% → 92% (w/ exercise)			

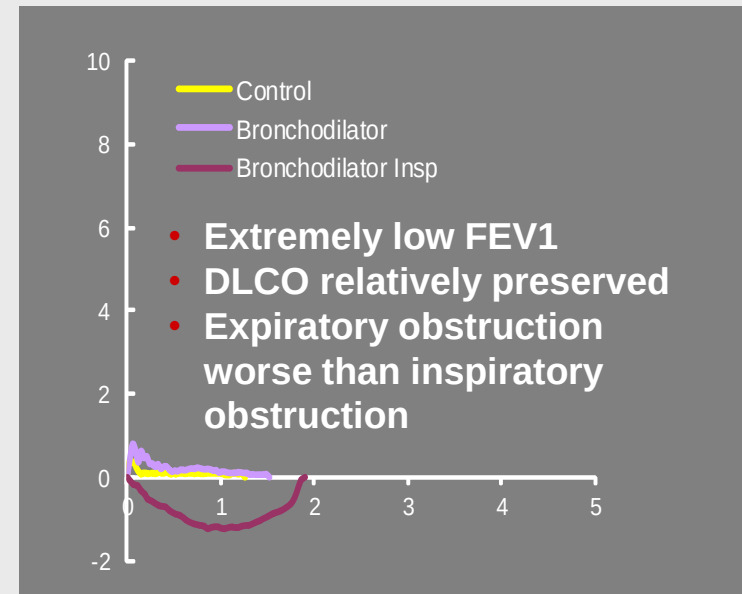


- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

64-year-old with severe dyspnea; former smoker of 25 pack-years, quit 4 months ago

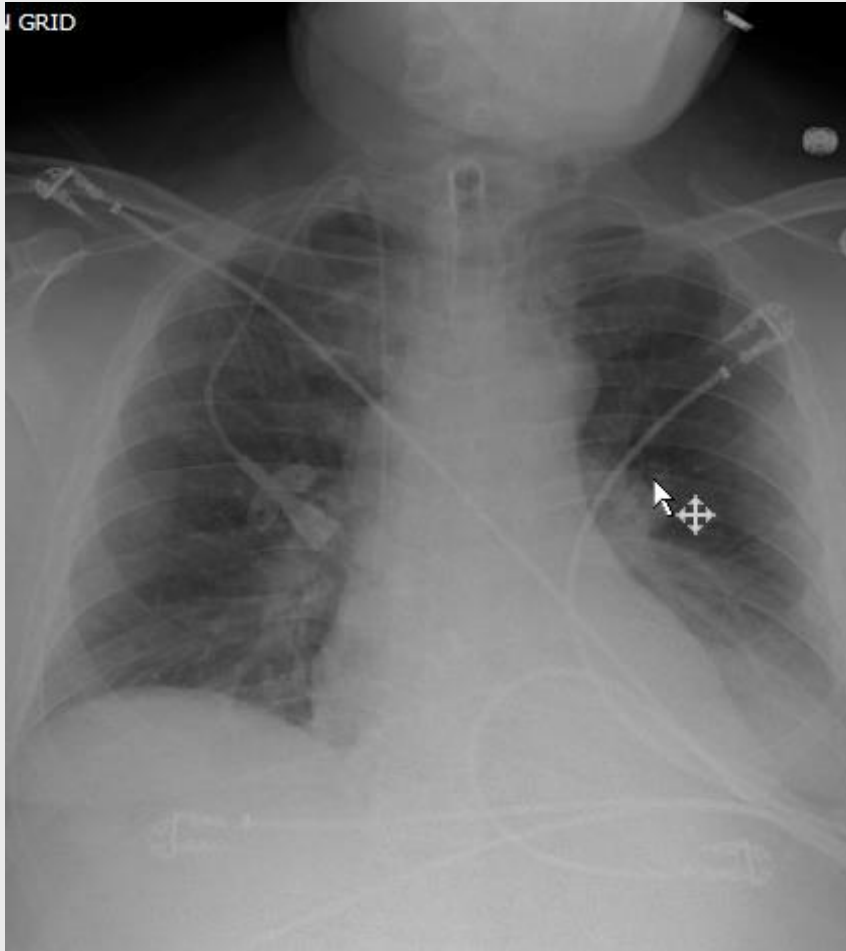
Ht: 145.8 Wt: 37.1

TLC	5.76	145%		
RV	3.69	227%		
RV/TLC	64.0	157%		
FVC	1.26	54%	1.52	+20%
FEV ₁	0.16	8%	0.28	+72%
FEV ₁ /FVC	13.0			
FEFmax	0.6	13%		
FEF25-75	0.1	4%		
DLCO	12	64%		
VA	3.61	91%		
SPO ₂	96% → 92% (w/ exercise)			

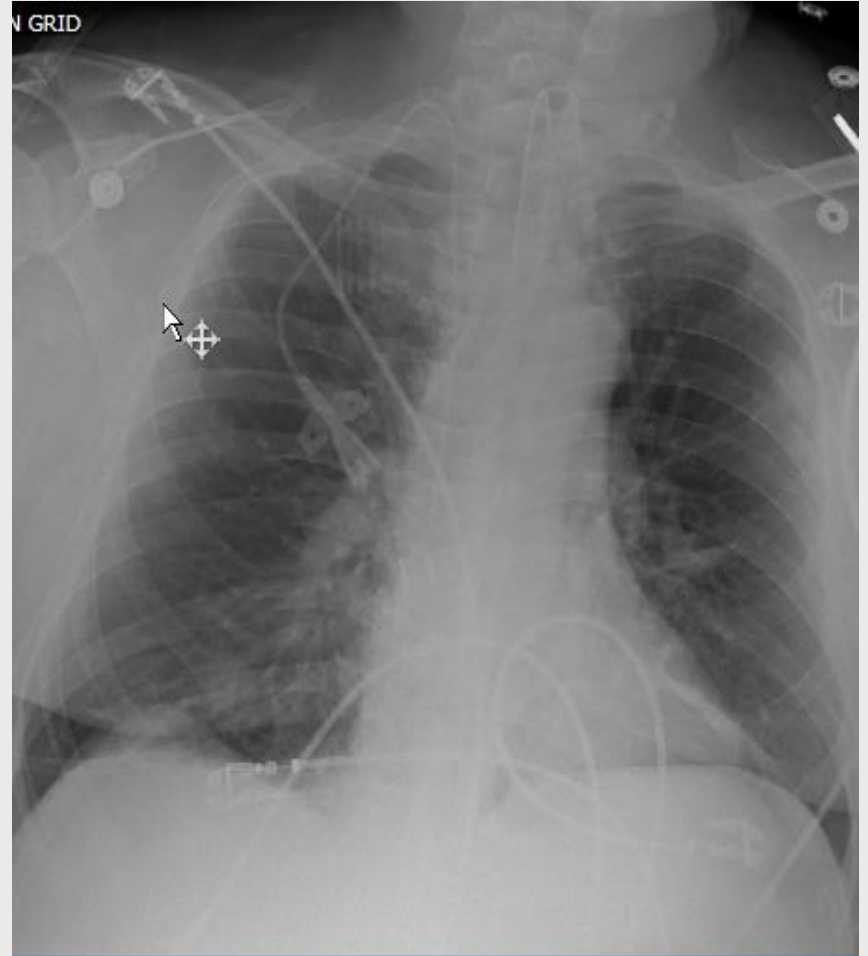


- A. Idiopathic pulmonary fibrosis (IPF)**
- B. Asthma**
- C. Tracheal stenosis due to prolonged intubation**
- D. Alpha 1-antitrypsin deficiency**
- E. Relapsing polychondritis**

Air Trapping in Tracheobronchomalacia

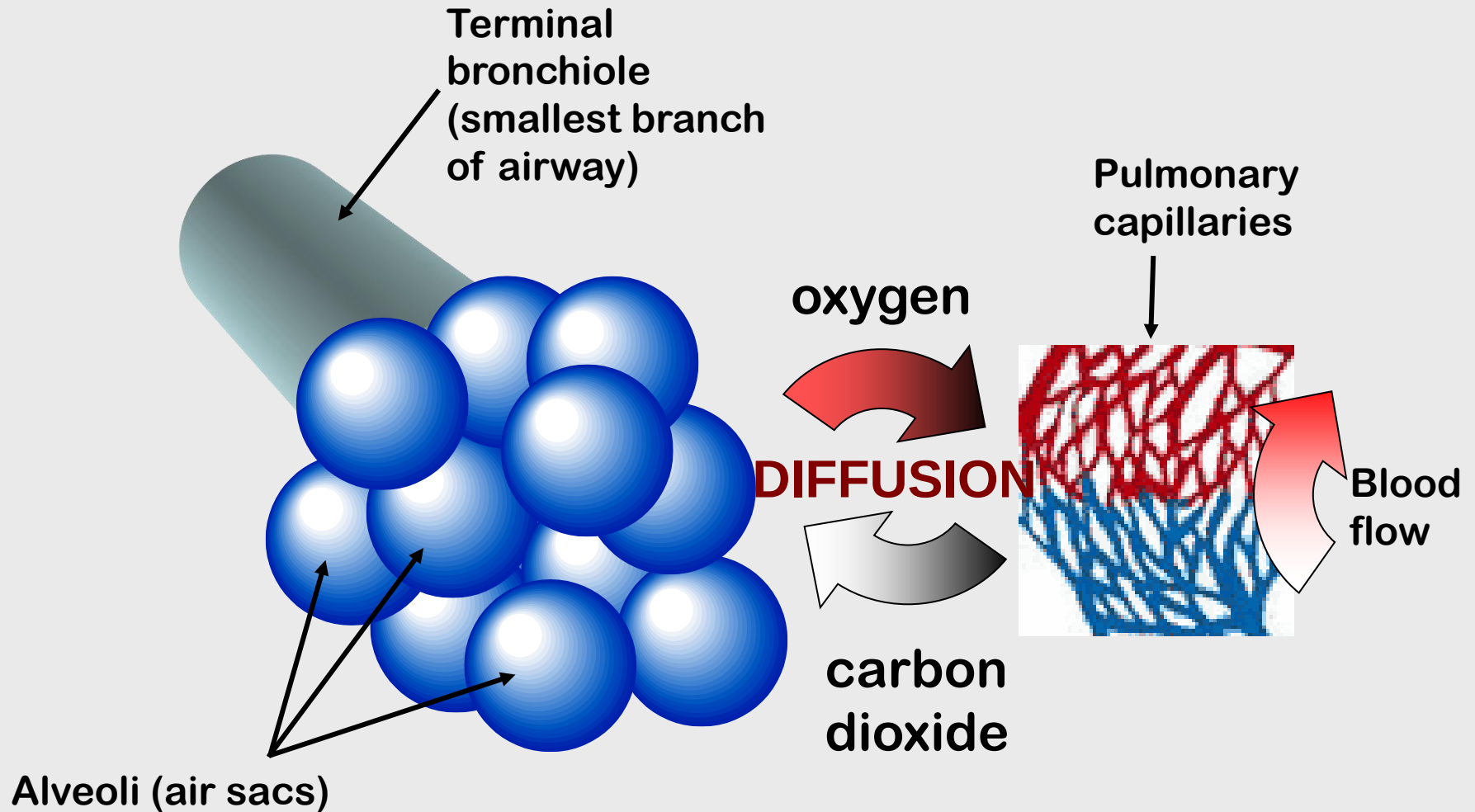


Time: 10:22 AM
Respiratory Rate = 20/min
Tidal Volume = 400 mL

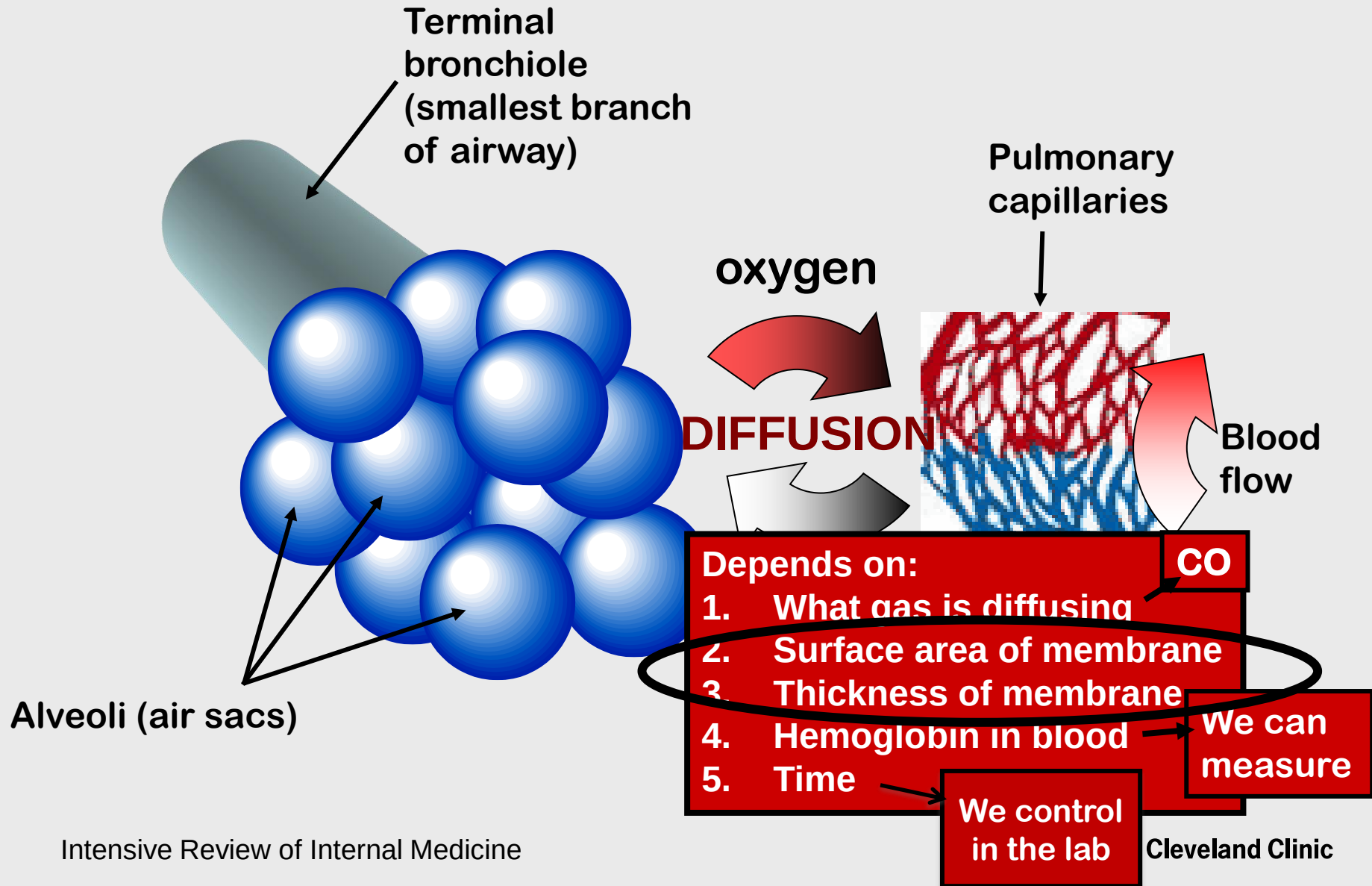


Time: 1:38 PM
Respiratory Rate = 40/min
Tidal Volume = 130 mL

Diffusing Capacity (DL_{CO})



Diffusing Capacity (DL_{CO})



36 yo researcher diagnosed with testicular cancer, treated with platinum and bleomycin. After first course of chemo, the patient had a really rough time with the platinum, with many GI side effects. Choice between 4 cycles without further bleomycin, or 3 cycles with it. The oncologist asks you if it is safe to give more bleomycin (with a better chance of cure) to the patient, in light of his diffusing capacity . . .

	3/29	4/25	5/2
D_Lco	22.4	15.9	18.2
	(68%)	(48%)	(55%)

↑
ChemoRx

Diffusing Capacity and More Bleomycin?

	3/29	4/25	5/2
D_Lco	22.4 (68%)	15.9 (48%)	18.2 (55%)
Hemoglobin	14.6	9.9	8.5



ChemoRx

Diffusing Capacity and More Bleomycin?

	3/29	4/25	5/2
D_Lco	22.4 (68%)	15.9 (48%)	18.2 (55%)
Hemoglobin	14.6	9.9	8.5
Corrected D_Lco	22.4 (68%)	19.1 (58%)	23.5 (71%)

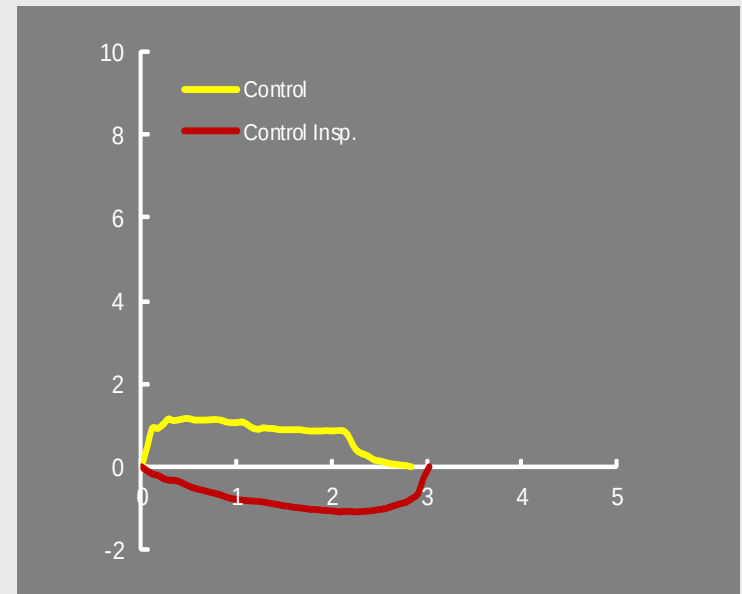


ChemoRx

57-year-old woman with severe dyspnea with cough & wheeze; never smoker

Ht: 160 Wt: 89.4 BMI: 34.9

FVC	2.84	91%
FEV ₁	1.12	44%
FEV ₁ /FVC	39.6	

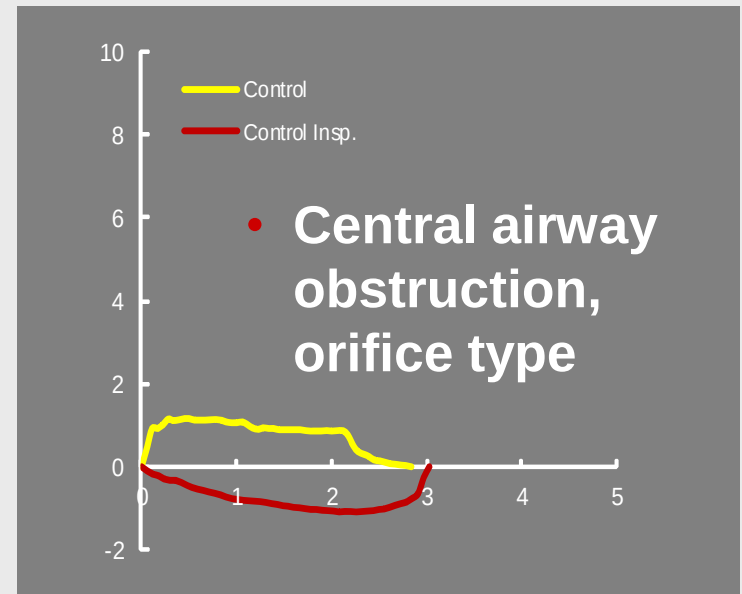


- A.** Idiopathic pulmonary fibrosis (IPF)
- B.** Asthma
- C.** Tracheal stenosis due to prolonged intubation
- D.** Alpha 1-antitrypsin deficiency
- E.** Relapsing polychondritis

57-year-old woman with severe dyspnea with cough & wheeze; never smoker

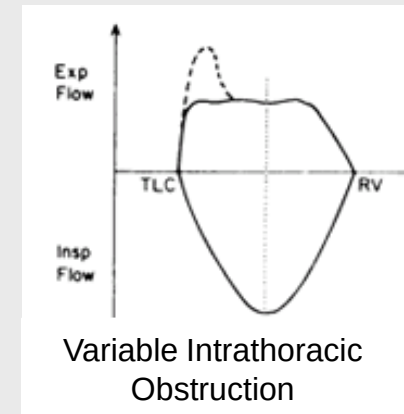
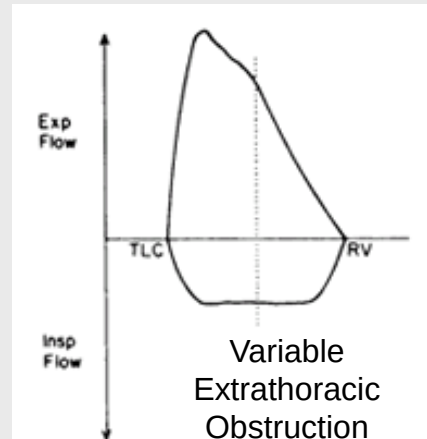
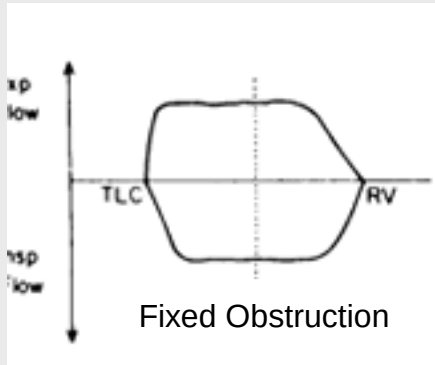
Ht: 160 Wt: 89.4 BMI: 34.9

FVC	2.84	91%
FEV ₁	1.12	44%
FEV ₁ /FVC	39.6	



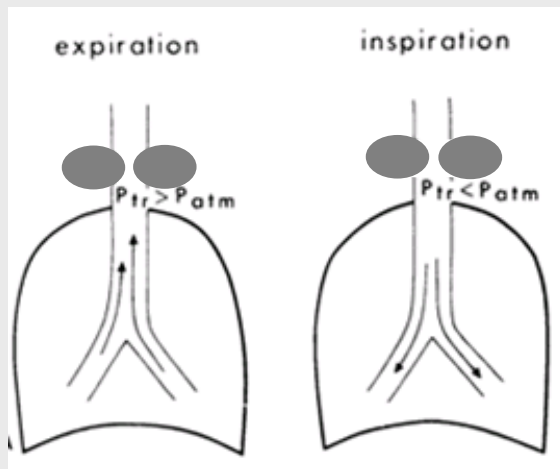
- A. Idiopathic pulmonary fibrosis (IPF)
- B. Asthma
- C. Tracheal stenosis due to prolonged intubation
- D. Alpha 1-antitrypsin deficiency
- E. Relapsing polychondritis

Airway Obstruction & Flow-volume Loops

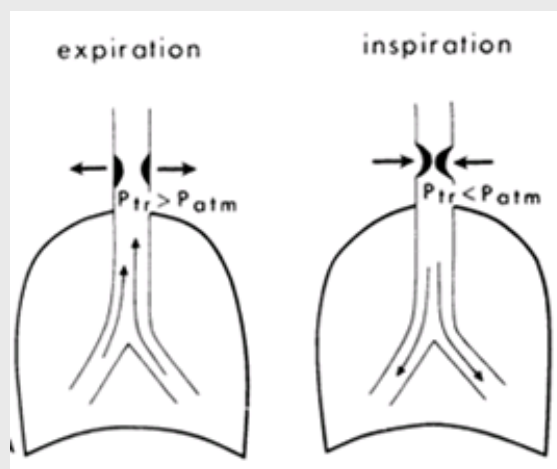


Expiratory pressure opens obstruction

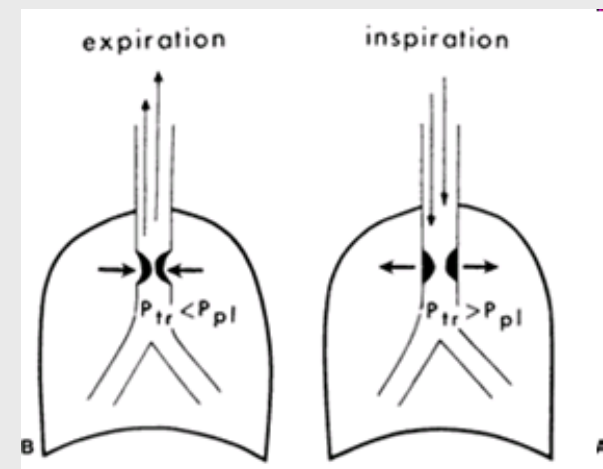
Expiratory pressure collapses obstruction



Tracheal stenosis
Extrinsic tumors
Migrated stents

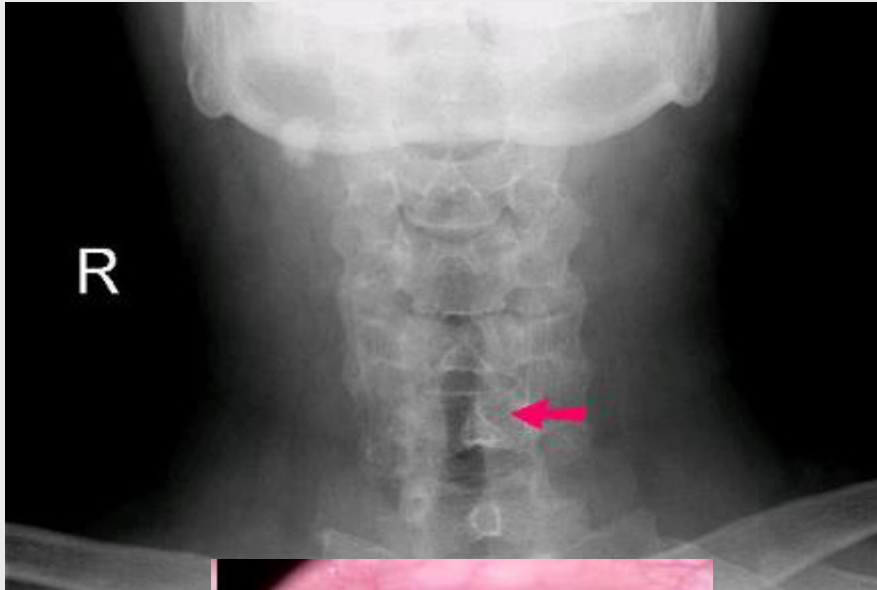


Goiter
Intrinsic tracheal tumors
Vocal cord paralysis



Lower tracheal tumors
Tracheomalacia
GPA
Relapsing polychondritis

Subglottic Stenosis



- **Commonest after prolonged intubation, but can occur after shorter tube times too.**
- **10-14 days is the rule of thumb.**