ATS 2024
Resident Boot Camp

PFT Interpretation

Learning objectives:

- Review the role of race in PFT interpretation
- Develop basic understanding of how PFT testing is conducted
- Define common physiology patterns that define normal versus disease
- Apply strategies for interpreting PFTs

Start with introductions around the table.
Explain this session is a safe space to discuss PFTs and an initial approach.
Encourage an open discussion with questions as you go. Explain it is case-based and we will go around the table.
Everyone will get an opportunity to do spirometry during 15 min of this session.
No expectation to get through all the cases. Cases and this teaching guide are published on the RBC wiki website.

Introduction to PFTs

- Goals
- Structure
- Resources

- Interpretation Strategy
- The use of race/ethnicity in PFTs

Goal of session is a brief intro to reduce anxiety and ease transition to fellowship
Structure of session is case based
Refer to resources on ATS wiki site and ATS Guidelines page

Start with introductions

Race and PFTs? What is the latest?

- In the US, race, ancestry, genetics & med are inextricably linked[1]
- New focus on reconsidering the use of race correction in clinical algorithms[2]
- Research showing e/o systemic racism in GFR measurements,[3] pulse ox[4]
- History of using PFTs to argue for racial differences as evidence of biologic inferiority[5]
- Observed differences likely relate to differential exposures and other social determinants of health
- Increasing evidence that race correction does not improve prediction of relevant outcomes[6,7]

[1] Borrell et al NEJM 2021
[2] Vyas et al NEJM 2020
[3] Diao et al NEJM 2021
[4] Sjoding et al NEJM 2021
[5] Braun et al CHEST 2020
[6] Baugh et al AJRCCM 2022
[7] Elmaleh-Sachs et al AJRCCM 2022

Published work has demonstrated reduced lung volumes in people of color compared to white populations. Correction factors or specific reference equations have been used. Many observed differences that have been attributed to race are related to differences in (particularly early childhood) exposures, pollution, and nutrition.
Furthermore, there is a history of using purported racial differences to demonstrate biologic differences that do not exist
Potential harm comes from a higher threshold for disability compensation or lung transplant eligibility
Race-based predictions do not predict clinically relevant COPD outcomes as well as race-neutral predictions in Spiromics and MESA-Lung cohorts. This data published after lit search for ATS/ERS task force and incorporated into ATS statement in 2023

Race and PFTs? What is the latest?

- ATS/ERS Statement in 2023 recommends use of race-neutral reference equations
- PFTs must be interpreted in context!
  - Clinical context
  - Longitudinal pattern
  - Should not serve as a binary indicator of health or illness

Bhakta N AJRCCM 2023; 978-995

GLI Global is a race neutral reference equation developed in 2022

New ATS/ERS Interpretive Strategies 2022

Update to 2005 recommendations:

- Use Global Lung Initiative (GLI) reference equations for spiro, lung volumes and DLCO with limits of normal >5% or <95%
  - Use race-neutral average ref equation: GLI Global recommended.
- Bronchodilator response defined as >10% improvement in FEV_1 or FVC relative to *predicted* FEV_1 or FVC
- Ignore DLCO/VA.
- Severity of lung function measures should be expressed as Z-scores:
  - Mild (z-score -1.645 to -2.5), moderate (-2.51 to -4), severe (<-4.1)

Stanojevic S ERJ 2022; 2101499
Bhakta N AJRCCM 2023; 978-995

Z-scores predict distance from normal compared to age-, sex-, and height-matched normals

z-score -1.645= 5%
-1.96 = 2.5%
-2.326= 1%
-2.5 = 0.62%
-4 = 0.003%

Added patterns including:

- Dysanapsis: Low FEV1/FVC ratio; normal FEV1. May be normal or reflect early obstruction.
- Nonspecific pattern: Normal FEV1/FVC ratio; low FEV1, FVC. May reflect decreased effort, restrictive pattern, or early small airways disease with air trapping. Full PFTs help.
- Defined two restrictive patterns: Simple = symmetric low TLC, FRC, RV; Complex: FVC reduced out of proportion to TLC reduction—indicates increased RV and difficulty with lung emptying (neuromuscular weakness, chest wall restriction, or occult small airway disease). ***These patterns are too complex for this interpretation.

Approach to PFTs

- Demographics
- Quality/Acceptability
- Spirometry pattern
  - Obstruction?
  - Bronchodilator Response
- Lung volumes
  - Hyperinflation
  - Restriction
- DLCO
- Flow volume loops

<u>Patterns of Impairment</u>

- Obstructive ventilatory impairment
- Restrictive ventilatory impairment
- Gas transfer impairment

Why do we obtain PFTs?

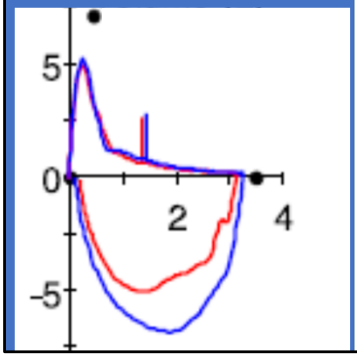
- Determine a pattern of abnormality that leads to diagnosis
- Assess treatment response
- Prognosis
- Preoperative risk assessment (incl lung resection)
- Determine disability
- Public health/population screening (e.g. firefighters, miners)

How do we derive normal values?

Case 1:
74 yo man w dyspnea

Ht 67”
Wt 141 lbs, BMI 22

Tob: Never Smoker



Comments: Good patient effort, cooperation and comprehension. The reported results meet ATS criteria for acceptability and repeatability.

	Pre-Bronch				
	LLN	Z Score	Pred	Actual	%Pred
—- SPIROMETRY —-					
FVC (L)	2.57	-0.59	3.47	3.15	90
FEV1 (L)	1.90	-2.76	2.62	1.38	52
FEV1/FVC (%)	62.93	-3.21	76.83	43.78	56
—- LUNG VOLUMES —-					
TLC (Pleth) (L)	5.03	+1.63	6.41	7.79	121
TGV (L)	2.43	+1.99	3.49	5.12	146
RV (Pleth) (L)	1.38	+2.02	2.40	3.96	164
RV/TLC (Pleth) (%)	26	+1.67	38	51	134
---DIFFUSION ---					
DLCOcor (ml/min/mmHg)	16.72	-2.12	22.93	15.14	66
VA (L)	4.59	-0.26	5.71	5.53	96
DL/VA (ml/min/mmHg/L)	2.93	-1.96	4.00	2.74	68

*First orient the learners to PFT layout. Then invite volunteer to interpret.
*Good quality study (meets ATS criteria)—this will be left off other cases, but all meet ATS criteria.
Obstructive pattern with moderate airflow limitation. **Hyperinflation** vs air trapping (FRC and RV increased). **Impaired gas transfer** (Decreased DLCO). Preserved VA suggests relatively preserved lung volumes.
Diff dx: COPD with emphysema; COPD with pulmonary vascular disease (PH, PE); combined pulmonary fibrosis and emphysema; concomitant anemia; Never smoker may suggest alpha1 antitrypsin def.
Teaching points:

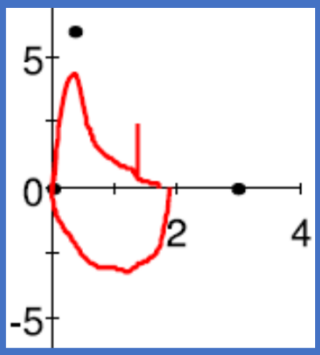
- TGV = Thoracic Gas Volume is FRC measured by plethysmography.
- Airflow limitation by either ATS criteria or GOLD in this case; moderate severity based on FEV1 z score of -2.76 (between -2.5 and -4)
- Hyperinflation (often defined as obstruction + inc’d TLC; we define as 2 of 3 inc’d: TLC, FRC, RV). Poor gas distribution based on difference between TLC and VA.
- Obstructive pattern on Flow Volume Loop (Note that black dots indicate predicted FVL)

[ATS criteria for spiro: good start (back extrapolation <5%FVC or 100mL); good ending (forced exp reaches plateau (<25mL exp in final sec or Texp 15s)); no sig cough (no cough in first sec); and repeatable (<=150mL or 10% highest value diff between best 2 FVC and FEV1)]

Case 2:
67 yo woman w dyspnea

Ht 65”
Wt 174 lbs, BMI 29

Tob Hx: none



	Pre-Bronch				
	LLN	Z Score	Pred	Actual	%Pred
–– SPIROMETRY ––					
FVC (L)	2.10	-2.40	2.95	1.73	58
FEV1 (L)	1.62	-2.18	2.30	1.38	59
FEV1/FVC (%)	66.06	+0.17	78.72	79.88	101
–– LUNG VOLUMES ––					
TLC (Pleth) (L)	4.18	-2.73	5.25	3.55	67
TGV (L)	2.08	-2.08	2.92	1.89	64
RV (Pleth) (L)	1.20	-0.61	1.99	1.68	84
RV/TLC (Pleth) (%)	26	+1.24	38	47	125
--- DIFFUSION ---					
DLCOcor (ml/min/mmHg)	14.96	-2.89	19.80	11.94	60
VA (L)	3.85	-3.40	4.80	2.95	61
DL/VA (ml/min/mmHg/L)	3.16	-0.16	4.15	4.05	97

Spirometry ***suggests*** restrictive pattern—reduced FVC, but normal ratio. (Also described as symmetric reduction in FEV and FVC.)

Lung volumes confirm restrictive pattern with reduced TLC, FRC with normal RV (Complex restriction based on TLC disproportionately less than FVC reduction—may reflect occult air trapping with small airways disease, component of neuromuscular weakness or early mixed disease (Simple restriction has symmetric reduction in TLC, FRC, RV)).
Gas transfer impairment based on reduced DLCO (and VA)—suggests loss of alveolar capillary structure.

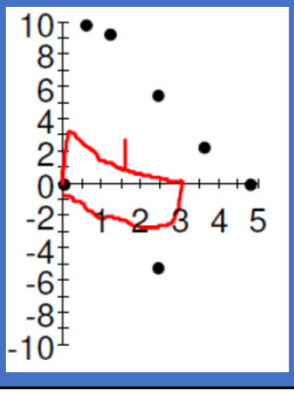
Diff Dx: Many forms of ILD (IIP, HP, CTD, others)

Additional teaching point: Isolated reduced DLCO is initial abnormality in early ILD. Advanced disease required before DLCO/VA is low. (This is why it was removed from new recs)

Case 3:
43 yo man w dyspnea

Ht 73”
Wt 293 lbs, BMI 39

Tob Hx: 17 pk years



	Pre-Bronch Actual	Pred	%Pred	LLN
--- SPIROMETRY ---				
FVC (L)	*3.05	4.78	*63	3.99
FEV1 (L)	*1.62	3.88	*41	3.24
FEV1/FVC (%)	*53	81	*65	68
--- LUNG VOLUMES ---				
SVC (L)	*3.21	5.59	*57	4.67
IC (L)	*2.71	4.10	*66	3.42
ERV (L)	*0.50	1.49	*33	1.24
TGV (L)	*2.15	3.64	*59	2.91
RV (Pleth) (L)	*1.65	2.15	*76	1.72
TLC (Pleth) (L)	*4.86	7.74	*62	6.19
--- DIFFUSION ---				
DLCOunc (ml/min/mmHg)	*18.36	31.24	*58	24.99
DLCOcor (ml/min/mmHg)		31.24		24.99
DL/VA (ml/min/mmHg/L)	4.09	4.22	96	3.38
VA (L)	*4.49	7.40	*60	6.18

Mixed pattern of airflow obstruction (low FEV/FVC ratio) **and restriction** with reduced lung volumes with **impaired gas exchange (**low DLCO).

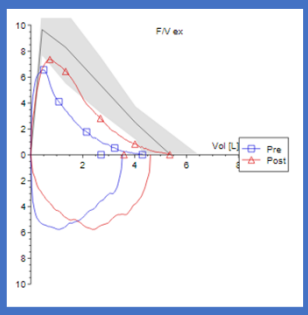
Mixed disease here may reflect asthma plus severe obesity; combined pulmonary fibrosis and emphysema; airways disease plus pulmonary fibrosis due to autoimmune disease, hypersensitivity pneumonitis, sarcoidosis, others.

Consider interpretation if only spirometry was available. “Airflow obstruction with reduced FVC is likely due to hyperinflation, but may suggest mixed disorder. Obtain lung volumes.”

Case 4:
33 yo man w dyspnea

Ht 72”
Wt 170 lbs, BMI 24

Tob Hx: 30 pk years



Spirometry

		PRED	PRE	PRE%PRED	POST	POST%PRED	%CHG	Z-SCORE
FVC	L	5.38	4.29	79.9	5.35	99.5	19.6	-1.67
FEV 1	L	4.39	2.70	61.5	3.58	81.5	20.0	-3.02
FEV1/FVC	%	82	63	76.7	67	81.7	5.0	-2.71

Lung Volumes

		PRED	PRE	PRE%PRED	Z-Score
VC	L	5.27	4.97	94.2	-0.54
TLC	L	7.13	7.35	103.1	0.32
RV	L	1.83	2.38	130.4	1.35
RV % TLC	%	27	32	120.7	1.02
FRCpleth	L	3.37	3.52	104.7	0.26
ERV	L	1.54	1.14	74.2	

Diffusing Capacity

		PRED	PRE	PRE%PRED	Z-SCORE
DLCO_SB	ml/(min*mmHg)	32.14	31.45	97.8	-0.15
DLCO/VA	ml/(min*mmHg*L)	4.85	4.62	95.4	-0.35

*Note new format here includes Z-scores, BD response is using new guidelines.

Baseline airflow obstruction with bronchodilator response. **Persistent airflow limitation despite albuterol suggests component of COPD**. Increased RV, but normal TLC, FRC. Normal DLCO. [This report doesn’t show LLN, but only z-scores—a Z score < -1.645 is below LLN; Z score of -3.02 for prebronchodilator FEV1 indicates moderate to severe airflow limitation (moderate is -2.5 to -4).

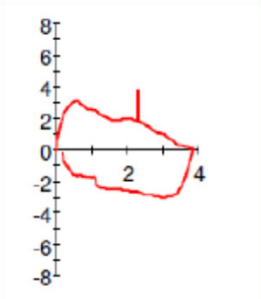
- Old ATS definition of bronchodilator response: Improvement in FEV1 **or** FVC by 12% **and** 200mL. 200 mL threshold is due to variability in test—a patient with severe obstruction might have an FEV1 of 600mL—a difference of 12% is only 70mL (well within the variability of the test).
- New ATS definition: Improvement in FEV1 **or** FVC by **10% of predicted FEV1 or FVC**.
  - BD response = FVCpost – FVCpre/Predicted FVC = 2.6-2.24/3.14= 11.4%
  - BD response = FEV1post –FEV1pre/Predicted FEV1 = 1.38-1.08/2.54= 11.8%
- The new definition minimizes effects of height, age, sex and is less affected by baseline lung function.

Case 5:

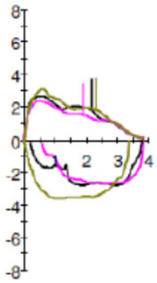
40yo man with dyspnea

Ht 67”
Wt 145 lbs, BMI 23

Tob Hx: 17 pk years



---- SPIROMETRY ----	Pred	LLN	Actual	%Pred
FVC (L)	4.82	3.95	3.85	79
FEV1 (L)	3.84	3.10	2.32	60
FEV1/FVC (%)	80	70	60	75



Spirometry shows airflow limitation with truncated inspiratory and expiratory flow volume loops. This suggests a fixed airway obstruction.

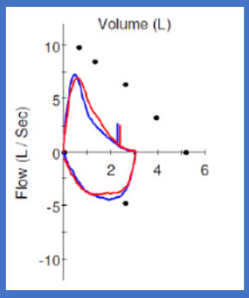
Repeat flow volume loops shows that each FVL is truncated. Remember truncation could reflect poor effort or weakness.
Consider reviewing patterns of variable extrathoracic and intrathoracic obstruction.

This patient had tracheal stenosis with a 9mm diameter airway.

Case 6:
57 yo man w dyspnea

Ht 72”
Wt 165lbs, BMI 22

Tob Hx: Never



	LLN	Pre-Bronch Pred	Pre-Bronch Actual	Pre-Bronch %Pred	Post-Bronch Actual	Post-Bronch %Pred	%Chng
---- LUNG VOLUMES ----							
TLC (Pleth) (L)		7.17	5.81	81	6.00	83	+3
TGV (L)		4.15	3.71	89	3.62	87	-2
RV (Pleth) (L)		2.47	2.69	108	2.81	113	+4
---- SPIROMETRY ----							
FVC (L)	4.21	5.20	3.08	59	3.06	58	+0
FEV1 (L)	3.12	3.96	2.30	57	2.43	61	+5
FEV1/FVC (%)	66	76	75	98	79	104	+6
DLCOunc (ml/min/mmHg)	27.56	37.22			30.47	81	
DLCOcor (ml/min/mmHg)	27.03	36.67					
VA (L)		7.26			4.70	64	
DL/VA (ml/min/mmHg/L)	3.45	5.13			6.48	126	

Stage	SIT PRE	SUPINE PRE
FVC (L)	3.08	1.45
% Change	+0	-53
% Pred	59	27

PFTs show normal lung volumes with symmetrically reduced spirometry (normal ratio, but FVC < LLN). No BD response. Low normal DLCO.
Lung volumes with reduced TLC and increased RV may suggest neuromuscular weakness. (This is complex restriction per new guidelines)

How do we assess respiratory strength?

- Maximal inspiratory and expiratory pressures (MIPs and MEPs—maximal pressure against closed valve).<60% considered abnormal.
- Maximal voluntary ventilation test—breathe as quickly and deeply as possible for 12 seconds.
- Upright and supine spirometry. A fall in supine FVC suggests diaphragmatic weakness. This patient has a fall of >50% in supine position.

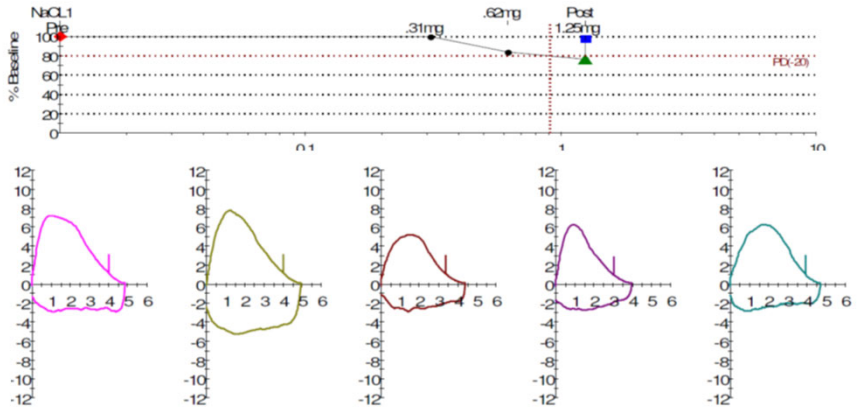
Case 7:
35 yo woman w dyspnea

Ht 70”
Wt 164lbs, BMI 24

Tob Hx: Never

Methacholine Test

Stage	Pre	NaCl	0.31mg/mL	0.62mg/mL	1.25mg/mL	Post	PC	PD
Dose	0.00	0.00	7.4mcg	14.8mcg	29.7mcg	0.00		
C.D.U.s	0.00	0.00	7.4mcg	22.3mcg	52.0mcg	52.0mcg		
FEV_1 (L)	4.11	4.02	4.03	3.38	3.08	3.94	0.91	22.8
% Change	+2	+0	+0	-15	-23	-2		
FVC (L)	5.07	4.88	4.93	4.40	3.98	4.71		
FEV_1/FVC (%)	81	83	82	77	77	84		

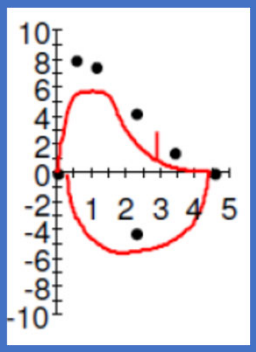


- Review methacholine test steps (baseline spirometry, spiro following saline, and then increasing concentrations of methacholine inhaled. Test stopped if FEV1 falls >20% or if patient reaches maximum concentration. Albuterol given if positive test or if FEV1 falls by 10% then post bronchodilator spirometry measured.
- ERS guidelines from 2017: A positive response (airways hyperresponsiveness) is described as PD20 (dose that results in 20% fall in FEV1). PD20 of <6mcg indicates marked airways hyperresponsiveness (AHR), 6-25 is moderate AHR, 25-100 is mild AHR, 100-400 is borderline AHR, >400 is normal.
- ATS guideline from 1999 described PC20 (concentration of methacholine that results in 20% fall in FEV1) of <0.25mg/mL marked AHR; 0.25-1 is moderate AHR; 1-4 is mild AHR; 4-16 is borderline; >16 is normal.
- PD20 preferred to PC20; it is intended to standardize dose across aerosol delivery methods.
- Other tests include exercise-induced bronchoprovocation; eucapnic voluntary hyperpnea; mannitol challenge
- This patient has flow volume loops that suggest variable extrathoracic obstruction (e.g. vocal cord dysfunction). Remember VCD and asthma may occur together.

Case 8:
80 yo man w dyspnea

Ht 73”
Wt 226 lbs, BMI 29

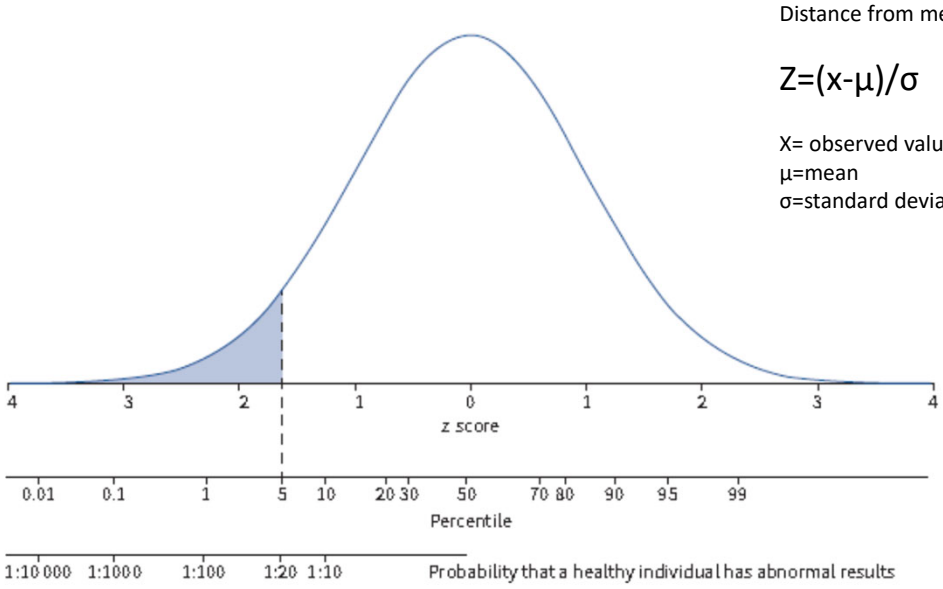
Tob: 30 pk yrs



	Pre-Bronch			
Spirometry	Actual	Pred	%Pred	LLN
FVC (L)	4.45	4.54	97	3.79
FEV_1 (L)	2.93	3.25	90	2.71
FEV_1/FVC (%)	66	72	91	60
Lung Volumes				
TLC (Pleth)(L)	6.25	7.74	80	6.19
TGV (L)	3.21	3.97	80	3.18
RV (Pleth) (L)	*1.99	2.96	67	2.37
Diffusion				
DLCOunc (ml/min/mmHg)	*15.83	22.81	69	18.25

Low normal lung volumes, spirometry with airflow limitation (according to GOLD, but not LLN); and low DLCO.

Diff dx: Isolated low DLCO may reflect early ILD, pulmonary vascular disease; severe anemia; early mixed obstruction and restriction.



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Z-scores predict distance from normal compared to age-, sex-, and height-matched normals

z-score -1.645= 5%
-1.96 = 2.5%
-2.326= 1%
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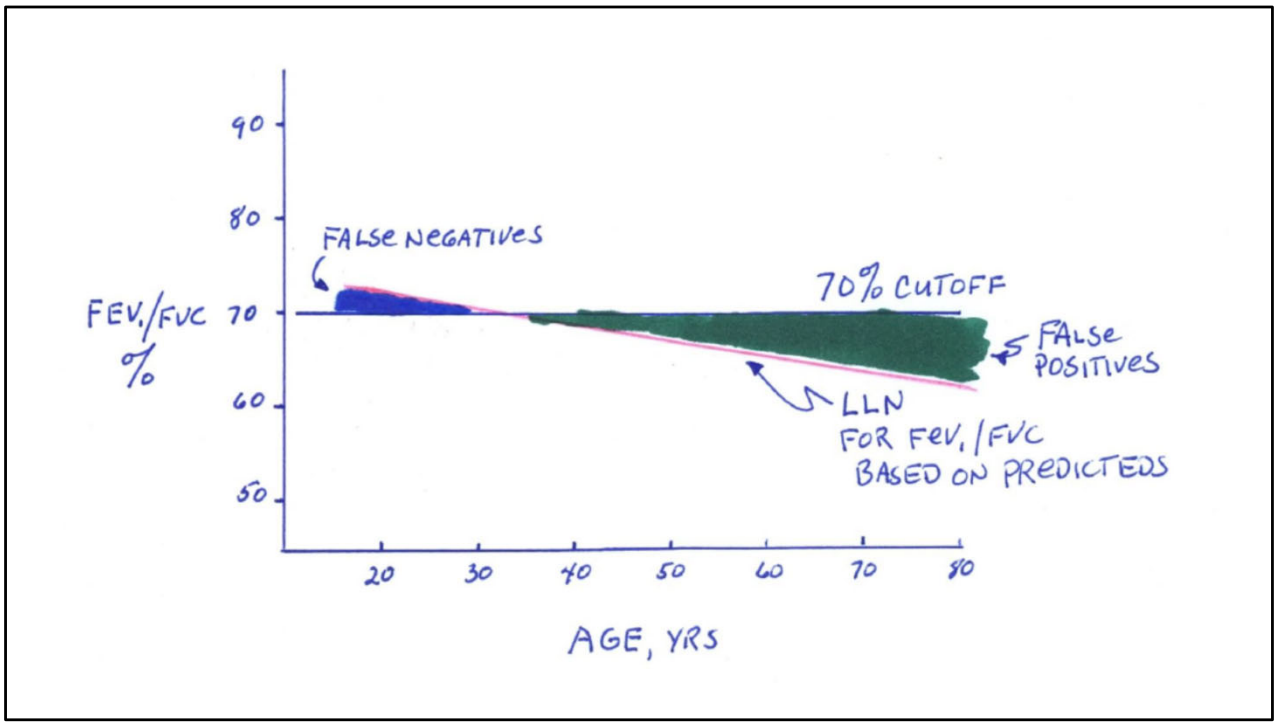
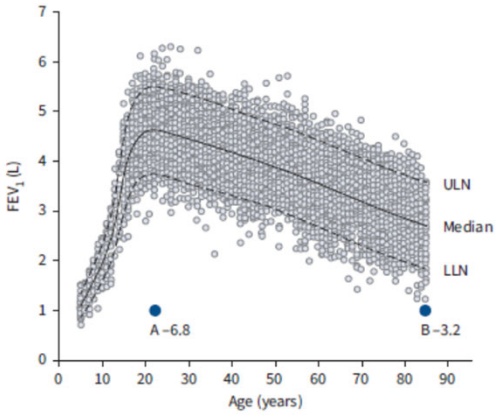
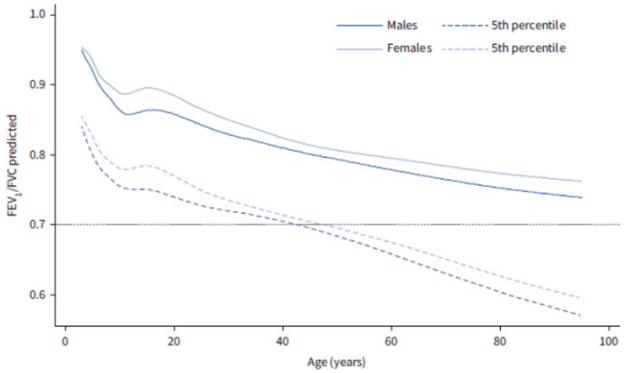


Optional to discuss challenge with GOLD criteria for airflow obstruction



Plot of population forced expiratory volume in 1 s (FEV1) data for males of median height for age between ages 5 and 85 years with the upper limit of normal (ULN; 95th percentile), lower limit of normal (LLN;5th percentile) and median predicted shown as derived from Global Lung Function Initiative spirometry equations [10]. The LLN for a man aged 22 years is 81.1% predicted but is 67.9% predicted for a man of the same median height aged 85 years. Participants A and B both have an FEV1 of 1.0 L, giving a z-score of −6.8 for individual A and −3.2 for individual B.



Forced expiratory volume in 1 s (FEV1)/forced vital capacity (FVC) predicted and lower limits of normal (5th percentile) compared with the fixed cut-off of 0.7.

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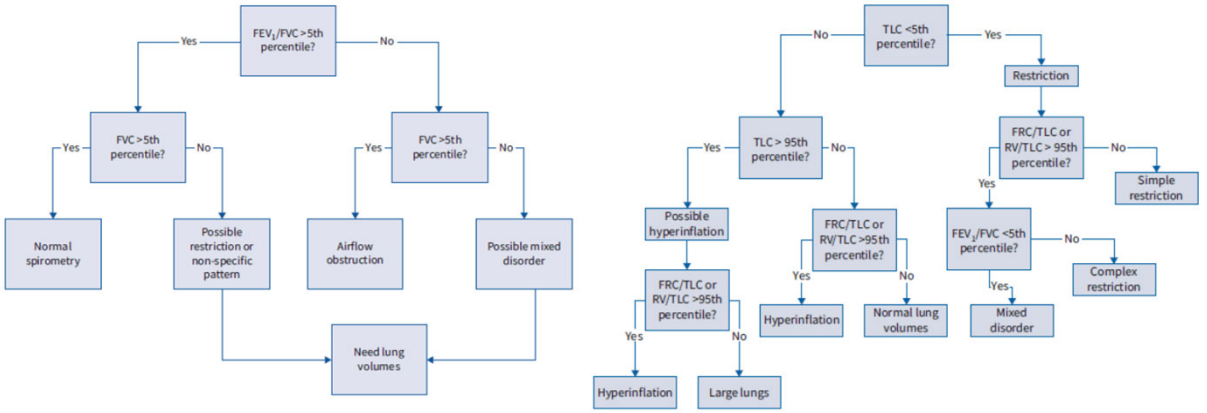

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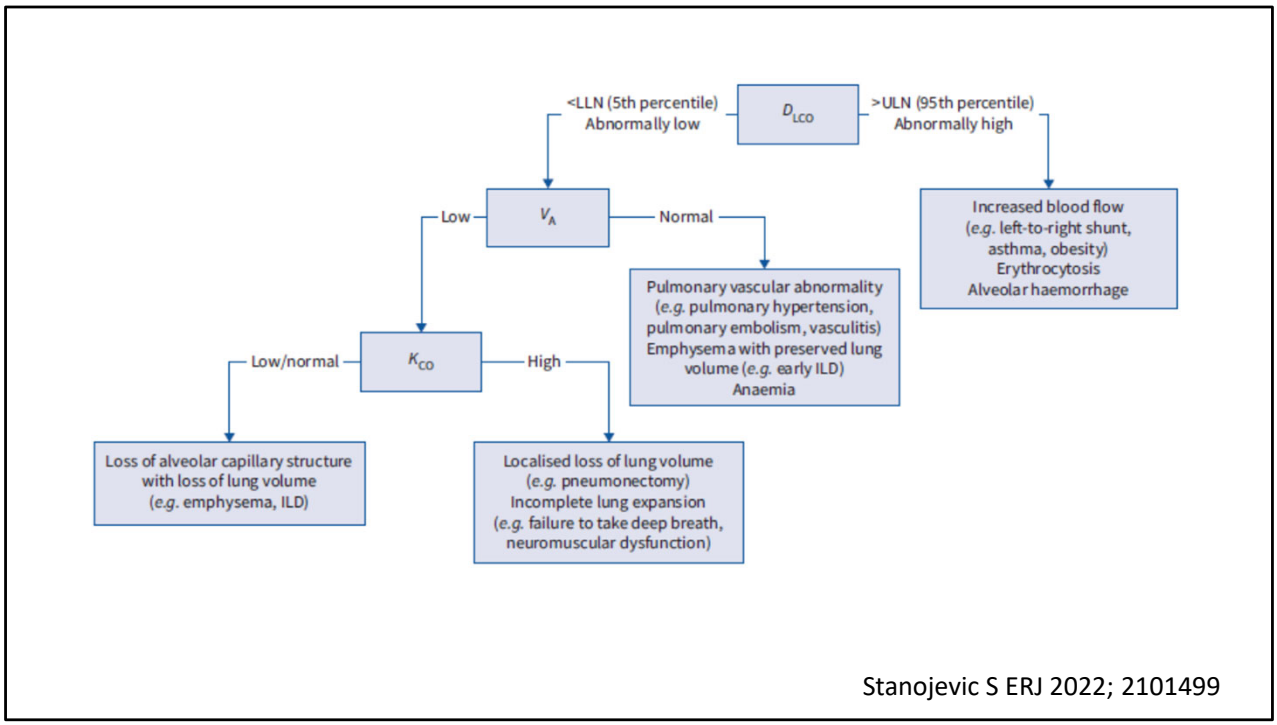

Stanojevic S ERJ 2022; 2101499

$D_{LCO} = K_{CO} \times V_A$ = Diffusion of the lung for carbon monoxide
V_A= Alveolar volume
K_{CO} = Transfer coefficient of the lung for CO = D_{LCO}/V_A