



Updates in Pulmonary Function Testing

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Objectives

- Understand **key updates** in PFT interpretation.
- Recognize the impact of the **new reference standards**.
- Learn about the revised criteria for **classifying severity** and significant **bronchodilator response**.
- To understand common **physiologic impairments** on PFTs.
- To develop an approach to **interpreting** PFTs.

Why Were the Guidelines Updated?

- Advances in research and understanding of lung physiology.
- Need for improved standardization and accuracy in interpretations.
- More accurate physiological assessment of lung disease.
- New severity classifications that standardize lung function impairment across patient populations.

Thompson, S et al. 2022

General Updates in PFT Interpretation

- 2005: PFTs used to aid clinical diagnosis.
- 2022: Emphasis on using PFTs for physiological classification and not clinical diagnosis.
- Greater emphasis on uncertainty of interpretation, especially near the lower limit of normal.
- PFTs represent only a **snapshot in time**.

Thompson, S et al. 2022

Defining Normal Ranges in PFTs

- 2005: LLN = 5th percentile
- 2022:
 - LLN = 5th percentile.
 - ULN = 95th percentile.
- FEV₁/FVC < 0.7 not recommended by ATS/ERS.
- 80% predicted threshold for normal not recommended.

Thompson, S et al. JGIM. 2022

Update in Reference Equations

PFT Aspect	ERS/ATS 2005		ERS/ATS 2022
	USA	Europe	
Spirometry	NHANES III recommended	No specific equations recommended	GLI (Global Lung Function Initiative) equations
Lung Volumes	No specific equations recommended		GLI equations
DLCO			GLI equations

Thompson, S et al. JGIM. 2022

Understanding GLI Reference Equations

- Global Lung Function Initiative (GLI) reference equations were developed to provide a standardized, global approach to PFT interpretation.
- Based on a large multiethnic dataset from healthy individuals worldwide.
- Provides continuous age-related equations rather than discrete age groups.
- More accurate and applicable across different populations.

Thompson, S et al. JGIM. 2022

GLI: Modernizing Reference Standards

- GLI equations are now available for: Spirometry, lung volumes, and DLCO
- Support standardized interpretation across an expansive age range (3-95 years old).

Thompson, S et al. JGIM. 2022

Comparing GLI vs NHANES III

Aspect	GLI	NHANES III
Age Range	3-95 years	8-80 years
Population	International, large, multi-ethnic cohorts	U.S. (White, Black, Mexican-American)
Equations for...	Spirometry, DLCO, lung volumes	Spirometry only
Racial/ethnic grouping	4 ancestry-based + "Other" composite	Fixed race-specific equations

Obesity (N). 5 of 44. 5/15/2022

GLI Reference Populations

Reference Population	Data source	Population/ancestral origin
White	Europe, Israel, Australia, USA, Canada, Brazil, Chile, Mexico, Uruguay, Venezuela, Algeria, Tunisia	White (European); Hispanic (European)
Black	African American	Black (North American)
South East Asian	Thailand, Taiwan, China	Asian
North East Asian	Japan, Korea	
Multiethnic	Average of the other four GLI groups	Multiracial; Black South Africa, India, Unknown

Obesity (N). 5 of 44. 5/15/2022

Applying GLI in Clinical Practice

- Use appropriate equations base on self-reported ancestry, if known.
- If unknown or uncertain: use GLI "Other" equation.
- Report the specific equation used in clinical documentation.
- Ensure consistency across serial measurements for an individual.
- No single equation fits all – interpret results in clinical context.

Obesity (N). 5 of 44. 5/15/2022

Limitations of the GLI Equations

- Not all global populations represented in the GLI datasets.
- GLI DLCO & lung volumes primarily based on European ancestry.
- No validated guidance for transgender individuals.
- "Other" composite equation is a mathematical blend, not a universal norm.
- Body proportions, environmental, & socioeconomic factors can affect interpretation.

Obesity (N). 5 of 44. 5/15/2022

Changes in Bronchodilator Response (BDR)

- **Old Approach (2005)**
 - BDR defined by absolute and relative changes based on consensus expert opinion.
- **New Approach (2022)**
 - Report BDR as relative change, based on predictive values.

Shepherd, S et al. JGIM 2022

Rationale Behind Updated BDR Criteria

- Reduced biases from baseline lung function differences (age, height, sex).
- More accurate reflection of physiological response rather than consensus expert opinion.

Shepherd, S et al. JGIM 2022

Bronchodilator Response Criteria

- **2005:** $\geq 12\%$ and 200 mL increase in FEV₁ or FVC
- **2022:** $> 10\%$ increase in FEV₁ or FVC relative to the individual's predicted value.

$$\frac{(\text{Postbronchodilator value} - \text{Prebronchodilator value}) * 100}{\text{Predicted value}}$$

Shepherd, S et al. JGIM 2022

Bronchodilator Response Example

- 50 yo male, height 170 cm, has pre-bronchodilator FEV₁ of 2 L and a post-bronchodilator FEV₁ of 2.4 L. The predicted FEV₁ is 3.32 L.

$$\frac{(\text{Postbronchodilator value} - \text{Prebronchodilator value}) * 100}{\text{Predicted value}}$$

$$\frac{(2.4 - 2.0) * 100}{3.32} = 12\%$$

Shepherd, S et al. JGIM 2022

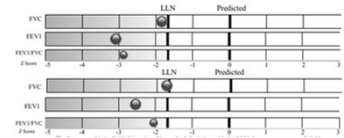
Redefining Severity Classification

- **2005:** Severity defined using % predicted values.
- **2022:** Severity now based on z-scores.

Shepherd, S et al. JGIM 2022

Z-Score Severity Classifications

- 3-Tier Severity Scale
 - Mild: -1.65 to -2.5
 - Moderate: -2.51 to -4
 - Severe: < -4.1



Shepherd, S et al. JGIM 2022

Recap of Major Updates

- Greater emphasis on physiological classification over diagnosis.
- Standardized reference equations with GLI.
- Shift to z-score classifications of severity.
- Bronchodilator response is now relative to an individual's predicted value.

Shepherd, S et al. JGIM 2022



Updates in Pulmonary Function Testing

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Interpreting PFTs

PFTs should be used to **identify abnormal physiology** rather than to make a specific clinical diagnosis.

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Lung function	Impairment classification
Airflow (inspiratory, expiratory)	Obstructive

Stanogovic S et al. ERS 2022

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Airflow (inspiratory, expiratory)	Obstructive
Lung volumes & capacities (TLC, RV, FRC)	Restrictive

Stanogovic S et al. ERS 2022

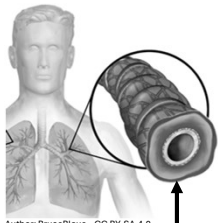
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Lung function	Impairment classification
Airflow (inspiratory, expiratory)	Obstructive
Lung volumes & capacities (TLC, RV, FRC)	Restrictive
Alveolar-capillary gas transfer (CO uptake over time)	Gas transfer

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Physiologic impairments

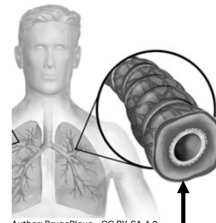


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Obstructive ventilatory impairment

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Physiologic impairments

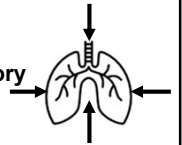


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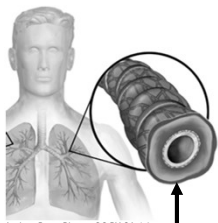
Obstructive ventilatory impairment

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Restrictive ventilatory impairment



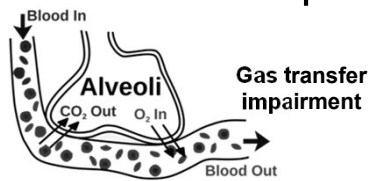
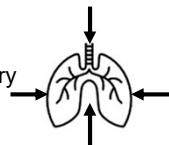
Physiologic impairments



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Obstructive ventilatory impairment

Restrictive ventilatory impairment



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Gas transfer impairment

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Obstructive ventilatory impairment

- Obstructive impairment is assessed by **spirometry**.
- **Main parameters: FEV₁ and FVC.**



Author: DataBase Center for Life Science (DBCLS) - CC BY 4.0

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- Obstructive impairment may be due to:
 1. Impaired expiratory muscle function



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 1. Impaired expiratory muscle function
 2. Obstruction of central airways



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- Obstructive impairment may be due to:
 1. Impaired expiratory muscle function
 2. Obstruction of central airways
 3. Small airways obstruction



FEV₁/FVC < LLN

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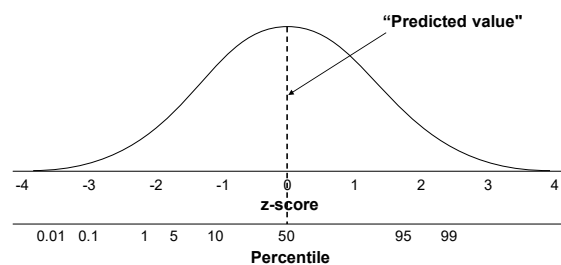
FEV₁/FVC < LLN
FEV₁ determines severity of obstruction

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Severity of lung function impairment

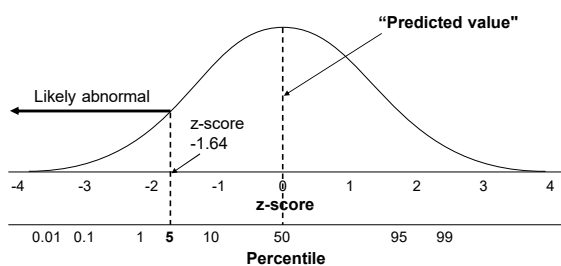
- New 2022 ERS/ATS standards **recommend against categorizing impairment using % predicted cut-offs.**
- Instead, recommend using **z-scores**: how far a lung function value is from the predicted value.
 - Accounts for sex, age, height, ancestry.
- Z-scores are expressed as a **standard deviation**.
- More consistent across age and sex than % predicted.

Z-score



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Z-score



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Severity of lung function impairment

ERS/ATS 2005		ERS/ATS 2022	
FEV ₁ % predicted	Severity classification	z-score	Severity classification
>70%	Mild	-1.65 to -2.5	Mild
60-69%	Moderate	-2.51 to -4	Moderate
50-59%	Moderately severe	< -4.1	Severe
35-49%	Severe		
<35%	Very severe		

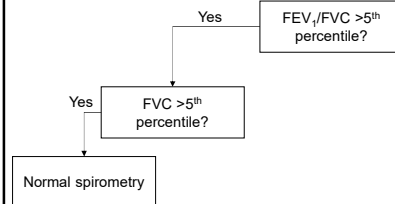
- **Note:** Severity of **lung function impairment** is not necessarily equivalent to **disease severity**!

Approach to interpreting spirometry

FEV₁/FVC >5th
percentile?

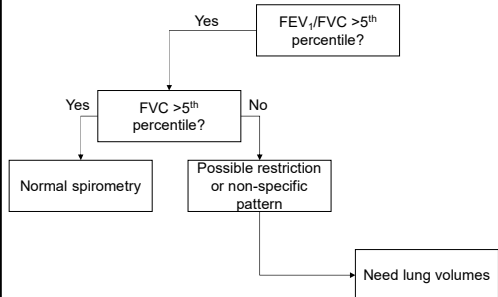
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Approach to interpreting spirometry



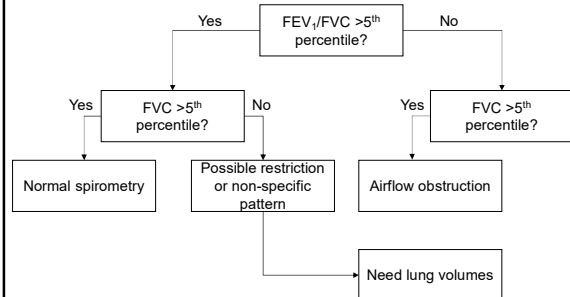
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Approach to interpreting spirometry



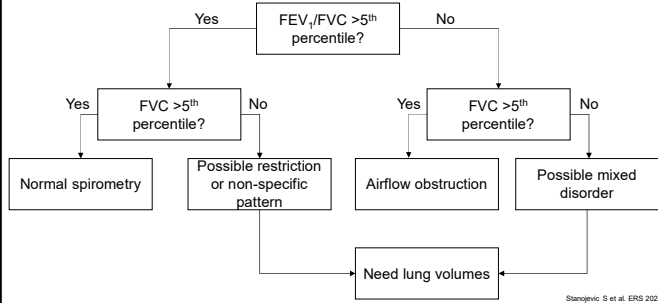
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Approach to interpreting spirometry



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Approach to interpreting spirometry



Restrictive ventilatory impairment

- Lung volumes are required to assess for **restrictive impairment**.
- May be assessed using:
 - Body plethysmography, or
 - Nitrogen wash-out

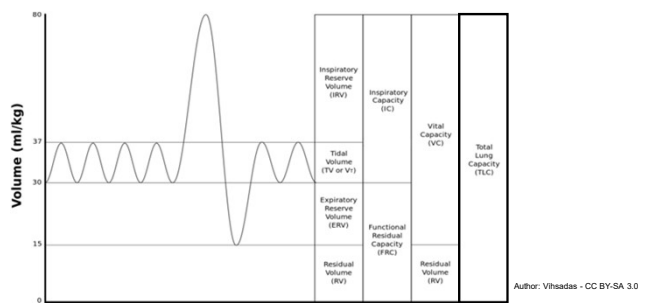


Author: Joe Mabel - CC BY-SA 3.0

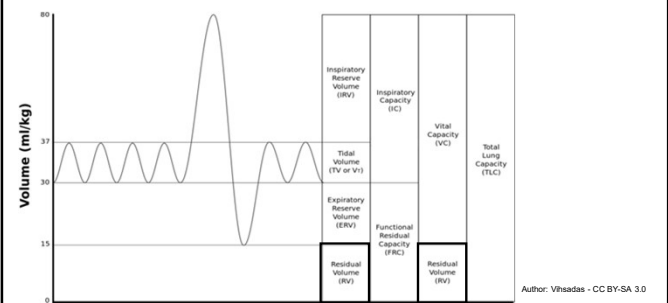
TLC < LLN

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Lung volume measurements



Lung volume measurements

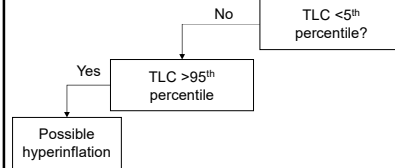


Approach to interpreting lung volumes

TLC <5th
percentile?

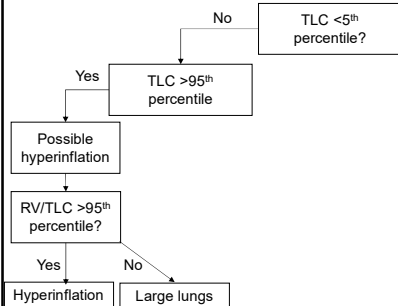
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Approach to interpreting lung volumes



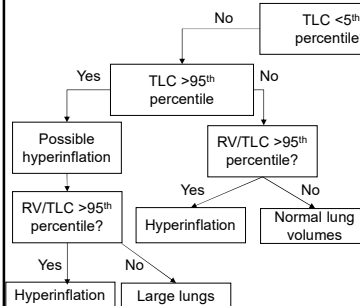
Stanoevic S et al. ERS 2022

Approach to interpreting lung volumes



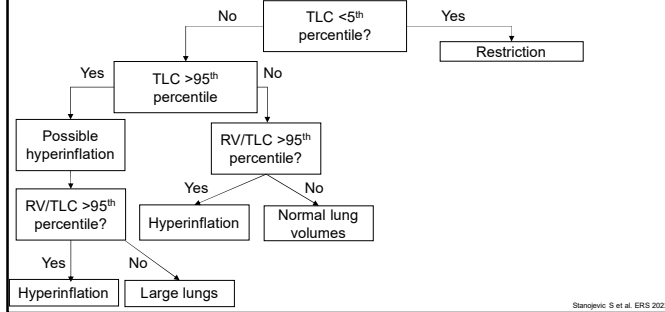
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Approach to interpreting lung volumes

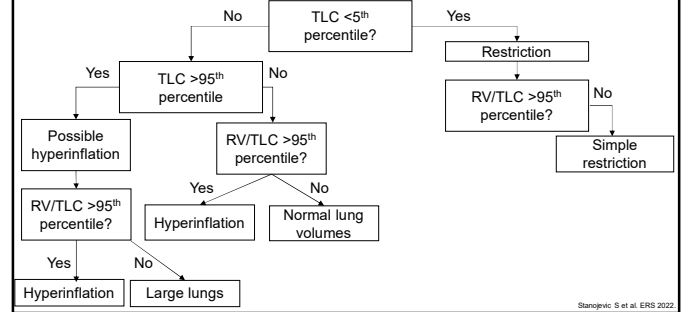


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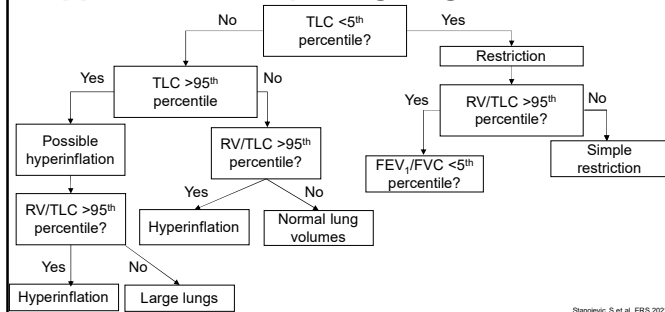
Approach to interpreting lung volumes



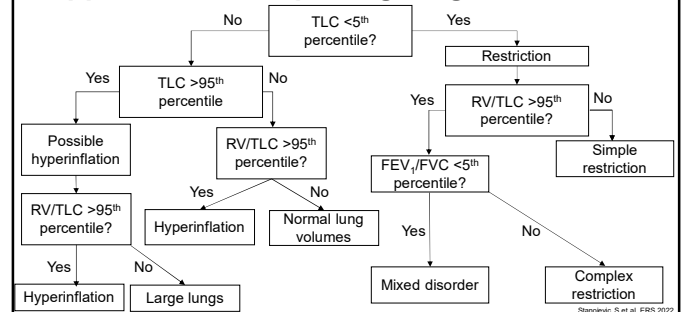
Approach to interpreting lung volumes



Approach to interpreting lung volumes

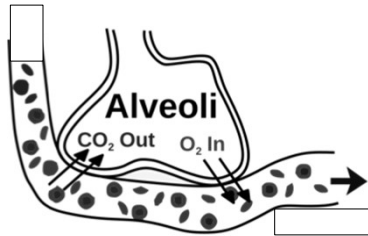


Approach to interpreting lung volumes



Gas transfer impairment

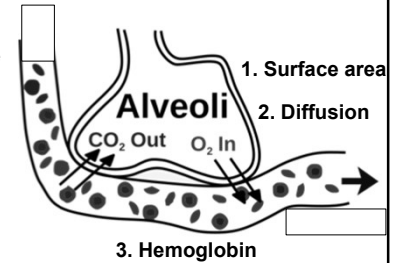
- Assessed by measuring the uptake of CO (surrogate for O_2) by the lungs (D_{LCO}).



Stanojevic S et al. ERS 2022.
Image Author: helia84 - CC BY-SA 3.0

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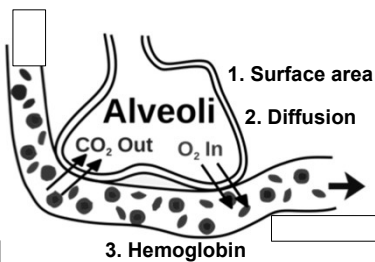
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Gas transfer impairment

$$D_{LCO} = K_{CO} \times V_A$$

- K_{CO} : Measured CO change over time
- V_A : Volume of gas containing CO

$$D_{LCO} < LLN$$



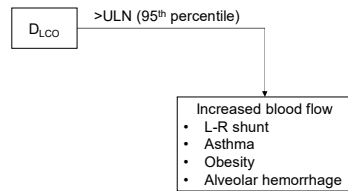
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Approach to interpreting DLCO

D_{LCO}

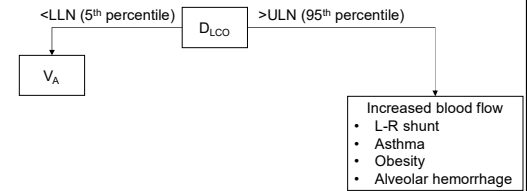
Stanojevic S et al. ERS 2022.

Approach to interpreting DLCO



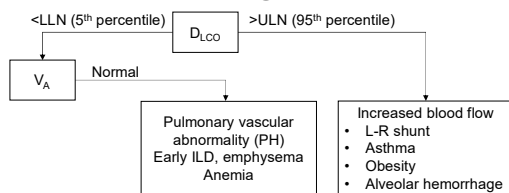
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Approach to interpreting DLCO



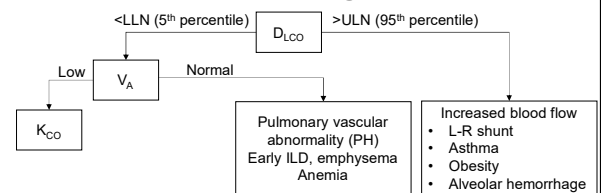
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Approach to interpreting DLCO



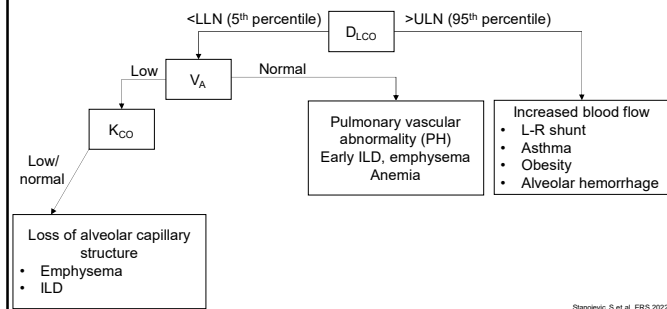
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Approach to interpreting DLCO

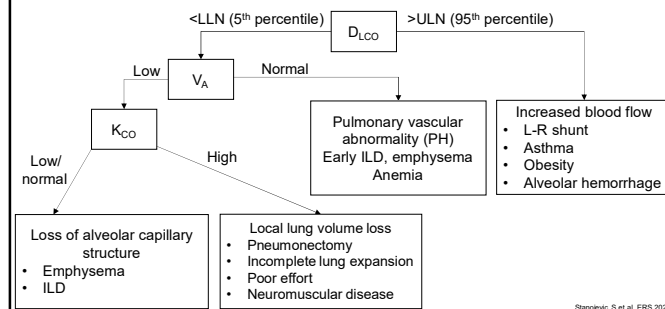


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Approach to interpreting DLCO



Approach to interpreting DLCO



42 yo F with chronic cough

42 yo F with chronic cough

Test Data									
	Pred	LLN	Pre	Pre %Pred	Pre ZScore	Post	Post %Pred	Post ZScore	Post %Change
--- SPIROMETRY ---									
FVC	2.35	1.66	1.43	61	-2.21	1.65	70	-1.67	9
FEV1	1.85	1.29	0.40	21	-3.91	0.48	25	-3.75	4
FEV1/FVC	0.80	0.67	0.28	35	-4.30	0.29	36	-4.27	2
Expired Time			11.92			11.40			-4
PEF L/s	5.08	3.56	1.49	29	-3.90	1.93	38	-3.41	30
FIF50			2.35			2.53			7
FVC/FEV1 Grade ATS			AA			AA			
MIP	-56	-17	-38	67	-0.77				

42 yo F with chronic cough

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FEV₁/FVC < LLN
Obstructive impairment

42 yo F with chronic cough

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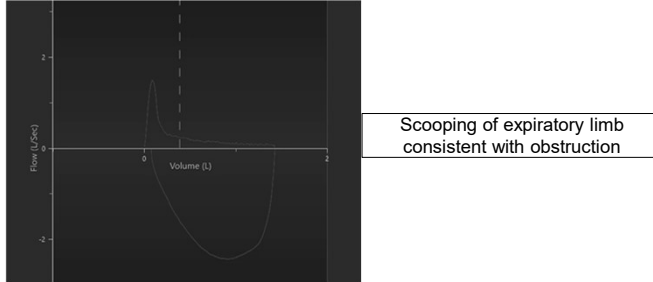
FEV₁ z-score -3.91
Moderate obstructive impairment

42 yo F with chronic cough

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FIF50			2.35			2.53			7
FVC/FEV1 Grade ATS			AA			AA			
MIP	-56								

No significant BD response

42 yo F with chronic cough



42 yo F with chronic cough

--- LUNG VOLUMES ---	pred	LLN	pre	%predicted	z-score			
SVC	2.35	1.66	1.45	61	-2.16			
IC	1.56		0.89	57				
ERV	0.78		0.49	62				
TGV	2.54	1.68	4.64	182	4.01			
RV (Pleth)	2.00	1.38	4.08	203	5.46			
TLC (Pleth)	4.49	3.61	5.53	123	1.94			
RV/TLC (Pleth)	44	35	74	169	5.54			
ATS (SVC)								

Elevated TLC
Mild hyperinflation

42 yo F with chronic cough

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IC	1.56		0.89	57				
ERV	0.78		0.49	62				
TGV	2.54	1.68	4.64	182	4.01			
RV (Pleth)	2.00	1.38	4.08	203	5.46			
TLC (Pleth)	4.49	3.61	5.53	123	1.94			
RV/TLC (Pleth)	44	35	74	169	5.54			
ATS (SVC)								

Elevated RV & RV/TLC
Severe air trapping

42 yo F with chronic cough

--- DIFFUSION ---	pred	LLN	pre	%predicted	z-score			
DLCOunc	17.21	12.95	5.03	29	-6.37			
DLCOcor	17.21	12.95	4.99	28	-6.41			
VA	4.00	3.20	3.51	87	-0.99			
Kco	4.31	3.29	1.42	33	-5.56			
BHT			11.28					
TLC (SB)			3.59					
DLCO Grade			CD					
ATS (DLCO)								

Low DLCO
Severely reduced diffusion capacity

42 yo F with chronic cough

--- DIFFUSION ---	pred	LLN	pre	%predicted	z-score			
DLCOunc	17.21	12.95	5.03	29	-6.37			
DLCOcor	17.21	12.95	4.99	28	-6.41			
VA	4.00	3.20	3.51	87	-0.99			
Kco	4.31	3.29	1.42	33	-5.56			
BHT			11.28					
TLC (SB)			3.59					
DLCO Grade			CD					
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DLCO Grade			CD					
ATS (DLCO)			●					

VA normal = preserved lung volumes
 K_{co} reduced = alveolar-capillary impairment

PFT interpretation reference

ERS/ATS technical standard on interpretative strategies for routine lung function tests 2022

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