The Latest & Greatest 2019 Update to the ATS/ERS Guidelines: Standardization of Spirometry

Seminar # 2503

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Disclosures

- No disclosures

- The views expressed are those of the presenter and do not reflect the official views or policy of the Department of Defense or its components

Learning Objectives

- Identify the source and relevance of the ATS/ERS guidelines for lung function testing and reporting
- Discuss the ATS/ERS recommendations for correct performance and reporting of spirometry
- Identify ATS/ERS guidelines to interpret and classify the severity of identified abnormalities

Sources

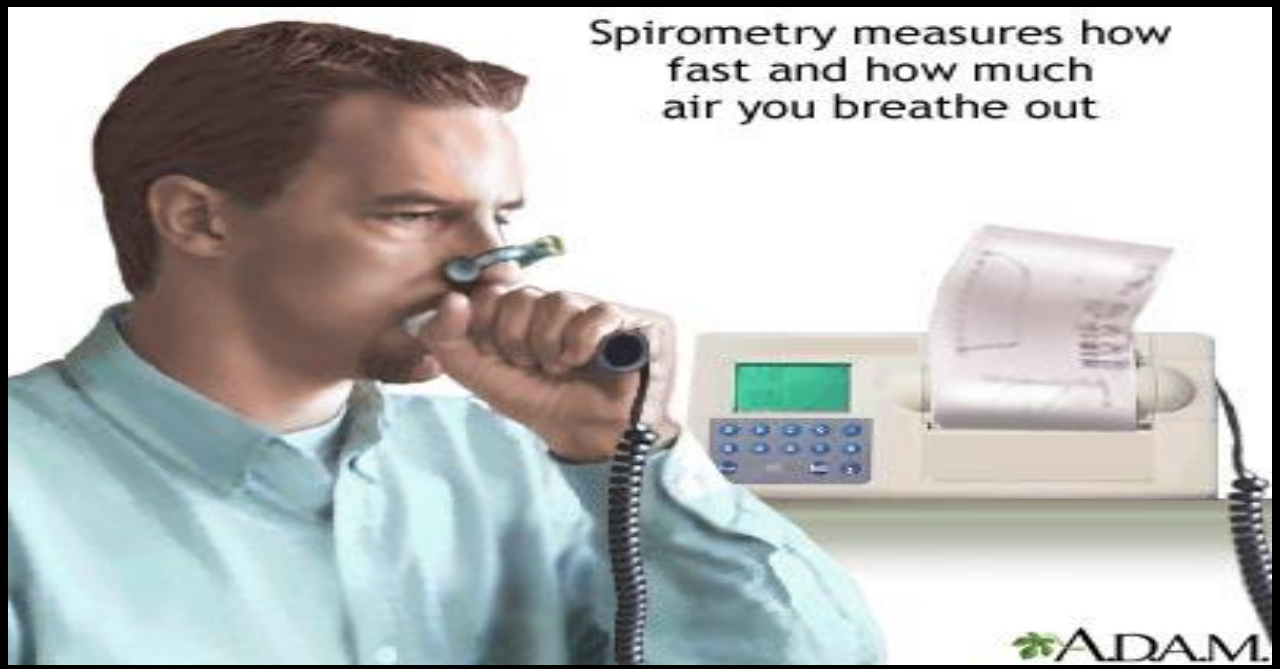
- ATS/ERS sources
  - Standardization of Spirometry 2019 Update - American Journal of Respiratory & Critical Care Medicine, Vol 200, 2019, 70-88.
  - Recommendations for a Standardized Pulmonary Function Report– American Journal of Respiratory & Critical Care Medicine, Vol 196, 2017, 1463-1472.
  - General considerations for lung function testing - European Respiratory Journal, Vol 26 (1), July 2005, pp 153-161
  - Standardisation of spirometry - European Respiratory Journal, Vol 26 (2), August 2005, pp 319-338
  - Interpretive strategies for lung function testing - European Respiratory Journal, Vol 26 (5), November 2005, pp 948-968.
  - ATS website = https://www.thoracic.org/statements/pulmonary-function.php

Overview

- Background
- Spirometry and ATS/ERS guidance
  - Performance of test – new 2019
  - Interpretation
    - Assessment of normal – new 2017 & 2019
    - Reference pools – new 2017
    - Determining adequacy – new 2017 & 2019
  - Approach to evaluation
  - Severity classification

Instrumentation

- Spirometer
  - Meets standards of ISO 26782 reviewed 2016

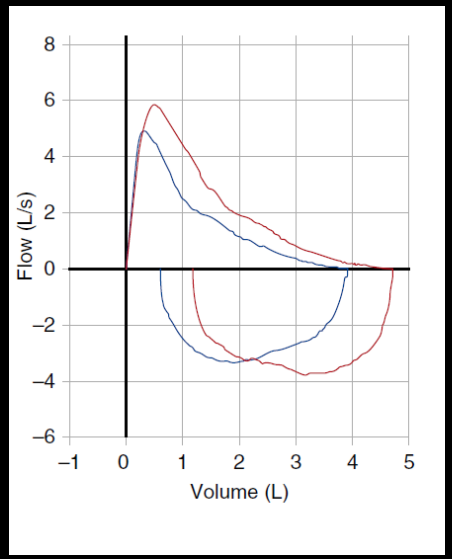


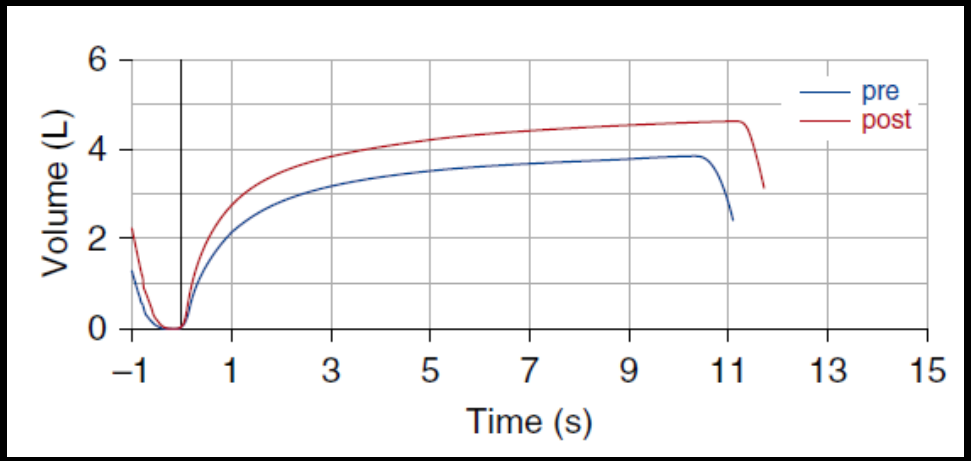
http://health.allrefer.com/pictures-images/spirometry.html

Am J Respir Crit Care Med 2019;200:70-88.

Instrumentation

- Spirometer
  - Meets standards of ISO 26782 reviewed 2016
  - Flow-volume and volume-time displays explicitly required





Am J Respir Crit Care Med 2019;200:70-88.

Instrumentation

- Spirometer
  - Meets standards of ISO 26782 reviewed 2016
  - Flow-volume and volume-time displays explicitly required
- 3 L calibration syringe for daily calibration

Am J Respir Crit Care Med 2019;200:70-88.

Performing Spirometry

- Preparatory instructions
  - Avoid smoking within 1 hour
  - Avoid alcohol/intoxicants within ~~4 hours~~ 8 hours
  - Avoid vigorous exercise within ~~30 min~~ 1 hour
  - Avoid constricting clothing of chest/abdomen
  - Avoid loose fitting dentures
- Prepare the subject
  - Ask about illness, pain, smoking, medication, etc
  - Measure standing height and weight
- Explain and demonstrate the test

Eur Respir J 2005;26:319-38.

Am J Respir Crit Care Med 2019;200:70-88.

Performing Spirometry

- Wash hands – operator and patient
- Quiet comfortable environment (drinking water, tissues)
- Patient in correct posture
  - Seated erect
  - Shoulders slightly back, chin elevated
  - Seated in chair with arms, without wheels, feet flat on floor
- Attach nose clips
- Ensure tight seal of mouth on mouthpiece (generally behind the teeth and on top of tongue)
- A well-trained, well-motivated, enthusiastic nurse or technologist is key

Am J Respir Crit Care Med 2019;200:70-88.

Performing Spirometry in COVID19 Era

- Screen patients acknowledging difficulties
- Limit tests to essential for immediate treatment decisions
- Reassess risk/benefits over time
- Measures to protect staff and patients
  - PPE that limits aerosolized droplet acquisition in accord with your infection control team
    - Gowns
    - Gloves
    - N-95
    - Face shield or googles
  - Enhanced cleaning, wiping down surfaces with appropriate cleansers
  - Negative pressure room if available (it is not for us)
  - Determine room air exchange to assess dormant interval between tests (1 hour for us)

https://www.thoracic.org/professionals/clinical-resources/disease-related-resources/pulmonary-function-laboratories.php

Performing Spirometry

Performing Spirometry

- Forced Vital Capacity Maneuver
  - From a maximal inspiration, the maximal volume of air exhaled with maximally forced effort
  - 4 distinct phases
    1. Maximal inspiration – largest source of error is inadequate maximal inspiration
    2. "Blast" of exhalation
    3. End of forced expiration (no volume change = plateau = <0.025 L over 1 sec) but no longer than 15 seconds – second largest source of error is ending prematurely
    4. Inspiration at maximal flow back to maximal lung volume

Am J Respir Crit Care Med 2019;200:70-88.

Performing Spirometry

- Exhale maximally and completely until no more air can be expelled (maintain posture)
- Use “vigorous” coaching (warn patient)
  - “Blast it out !!!” as opposed to “blow”
  - “Keep going, keep going !!!”, “More, more, more !!!”
  - “Squeeze it out … until your lungs are completely empty”
- There is no longer a minimum requirement for FET (previously 6 sec – adult; 3 sec – child)

Am J Respir Crit Care Med 2019;200:70-88.

Performing Spirometry

- Inspire with maximal effort until completely full
  - "Completely fill your lungs back up"
- Perform minimum of 3 maneuvers
  - No more than 8 are usually required
  - Except children may benefit from more than 8

Am J Respir Crit Care Med 2019;200:70-88.

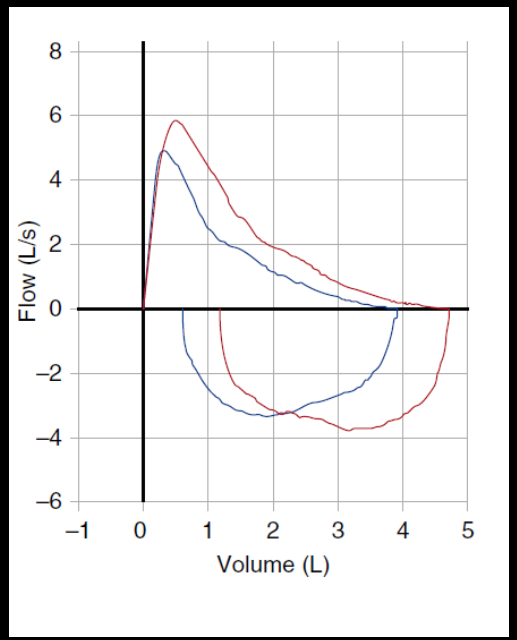
Most Common Errors

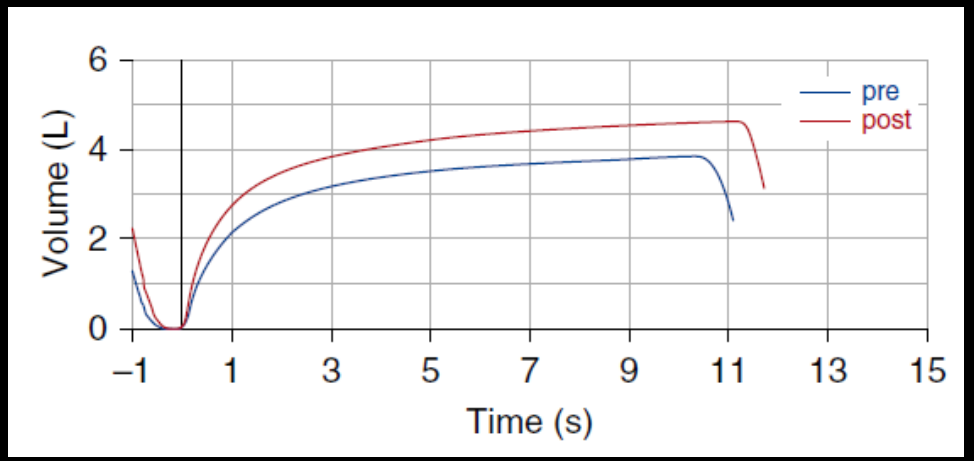
- Patient
  - Failure to take a complete inhalation prior to exhalation
  - Stops exhaling too soon
  - Slow test start = didn't "blast" out at beginning of test
  - Obstructed mouthpiece with teeth or tongue
  - Cough during test
- Technologist
  - Failure to request enough efforts to obtain best effort
  - Insufficient motivation & enthusiasm to obtain best effort

Am J Respir Crit Care Med 2019;200:70-88.

Clinical Data Gathered

- Forced Vital Capacity (FVC) maneuver
- Graphic displays
  - Flow Volume Loop – single best effort
  - Volume vs time curve – single best effort

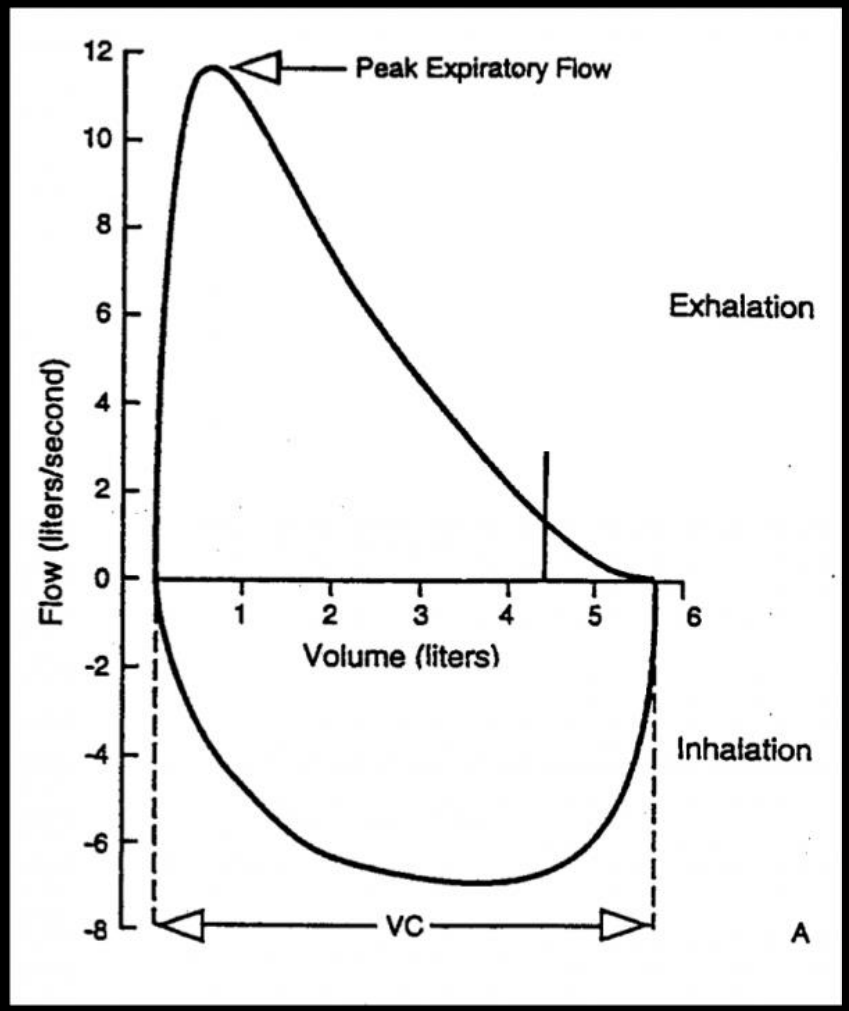




Flow-Volume Loops

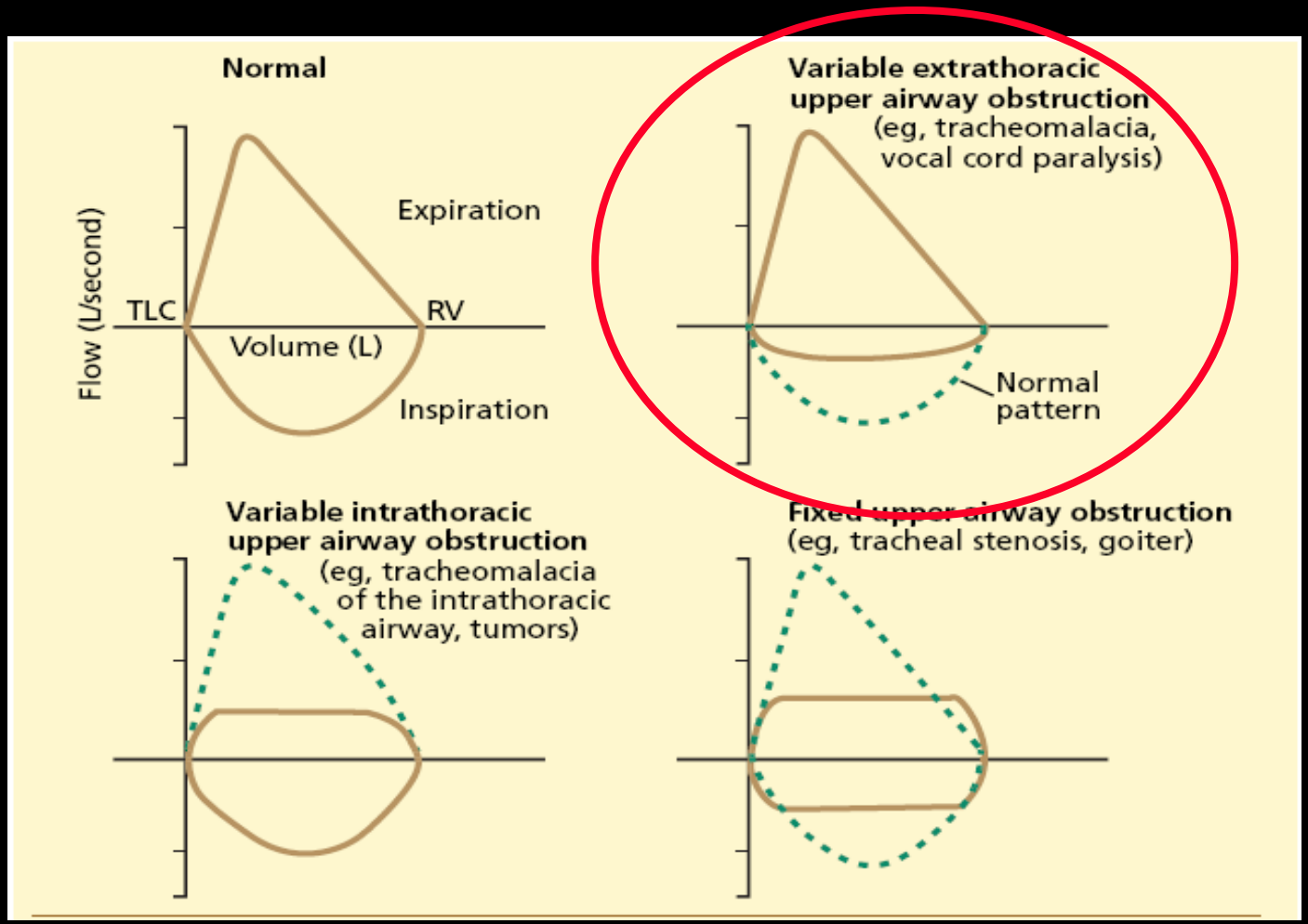
- Recognize characteristic patterns
- Recognize poor effort or mistakes
- Directly determine peak flow
- Directly determine FVC

Flow-Volume Loop



https://www.stepwards.com/?page_id=8403

Flow-Volume Loops: Patterns

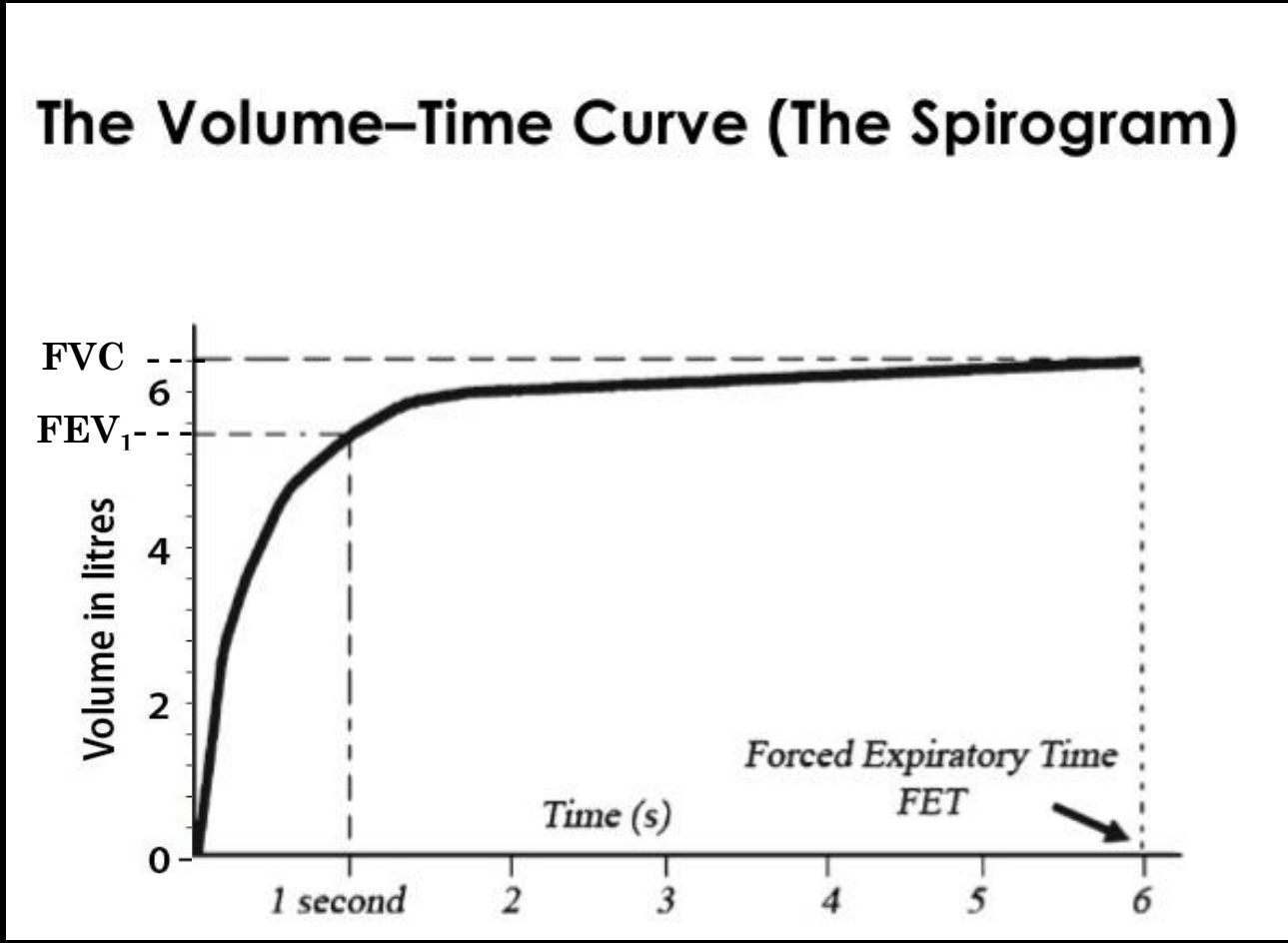


https://www.slideshare.net/arjunchhetri121/bedside-respiratory-assessment-spirometry

Volume vs Time Curve

- Recognize characteristic patterns
- Recognize poor effort or mistakes and when they occur during the maneuver
- Directly determine FEV1
- Directly determine total expiratory time (TET)
- Directly determine FVC

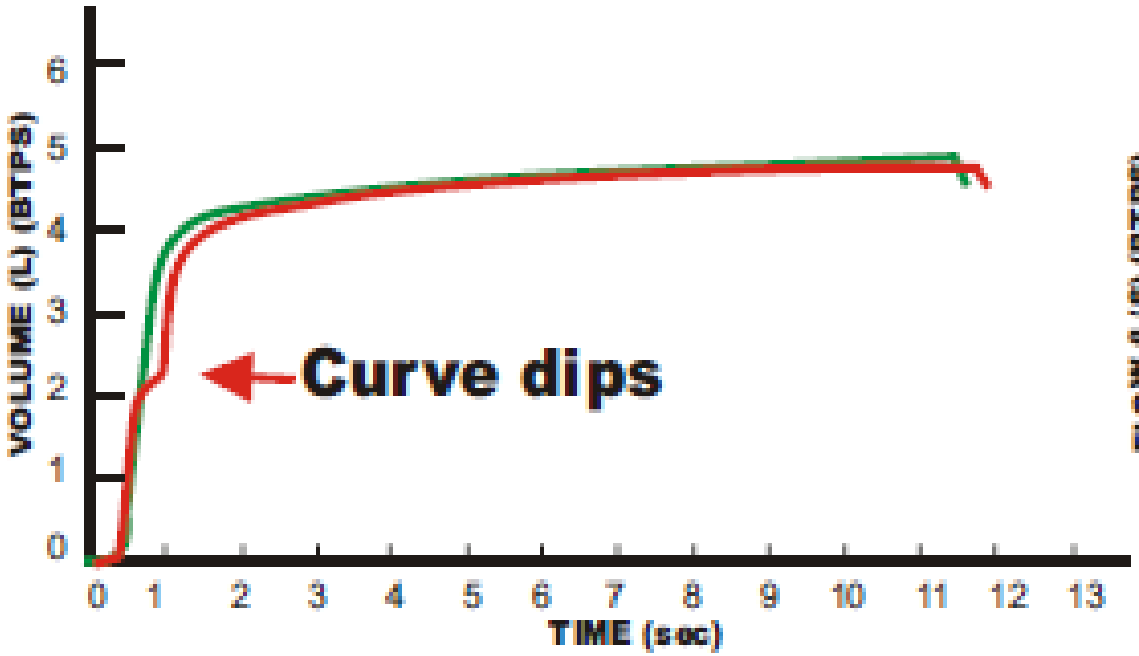
Volume vs Time Curve

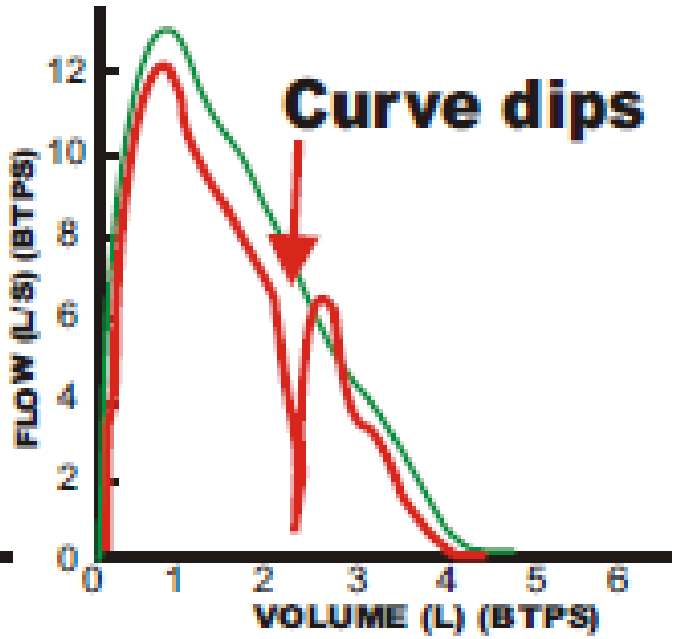


www.slideshare.net/ashrafeladawy/spirometry-basics

Cough in First Second

Delete Curve; Correction: Try a drink of water

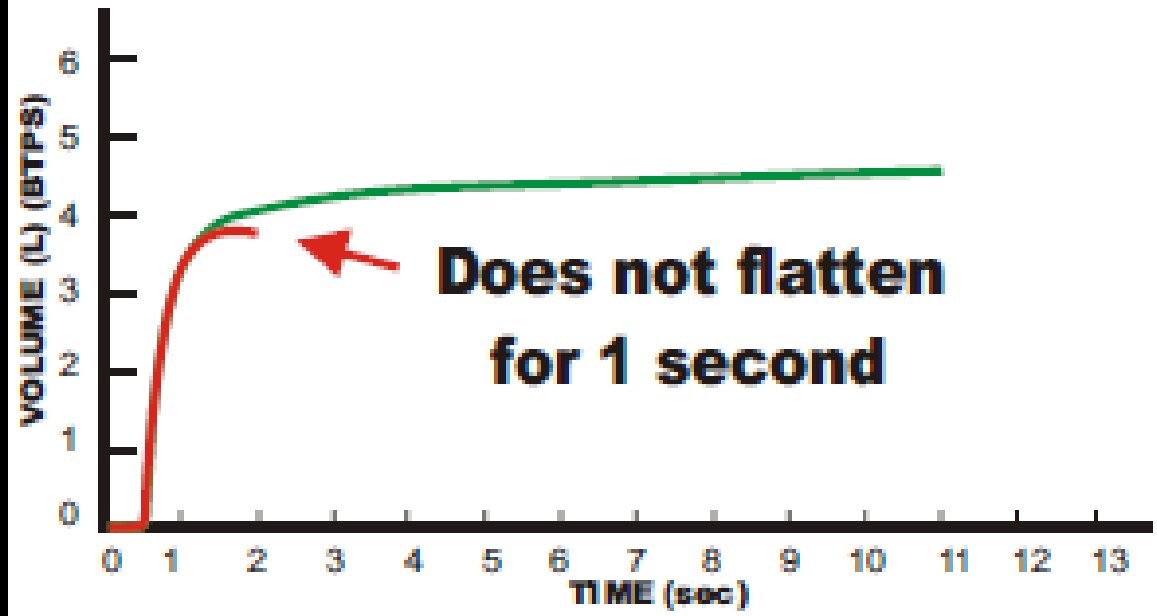


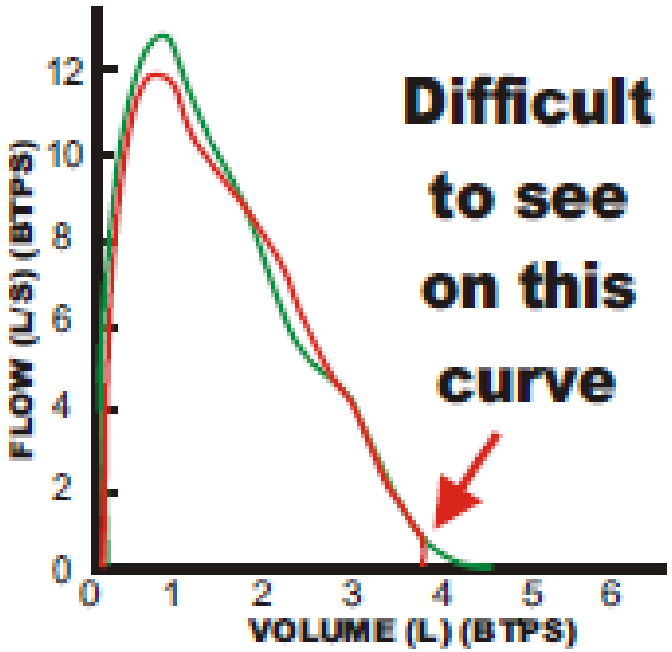


DHHS (NIOSH) Publication No. 2011-135

No Plateau Before 15 Seconds

Coach: Keep blowing until told to stop

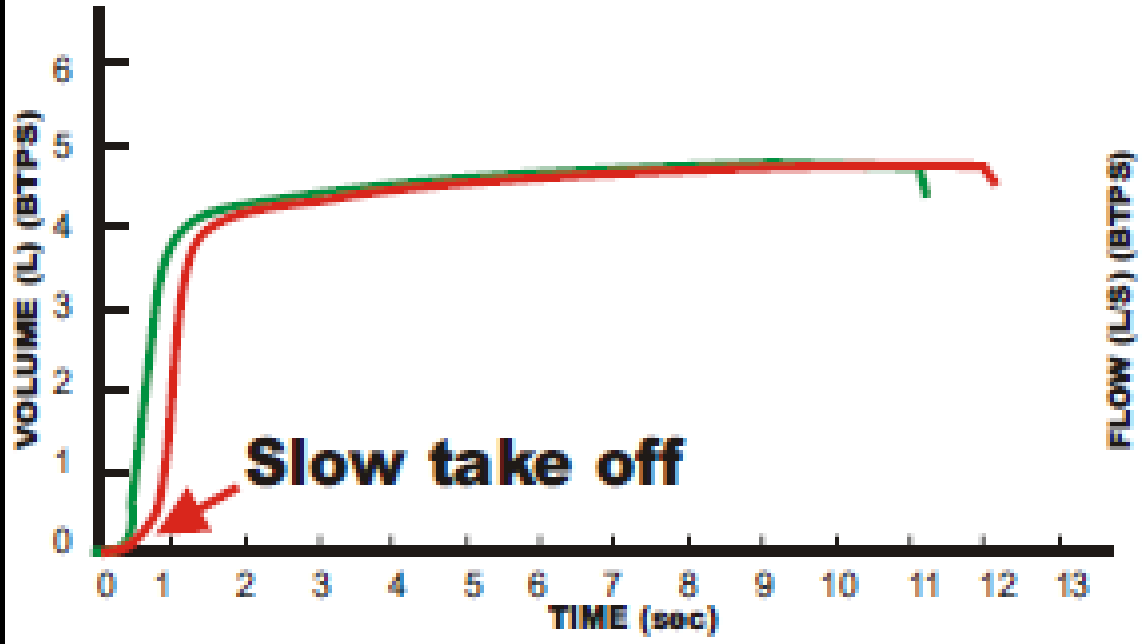


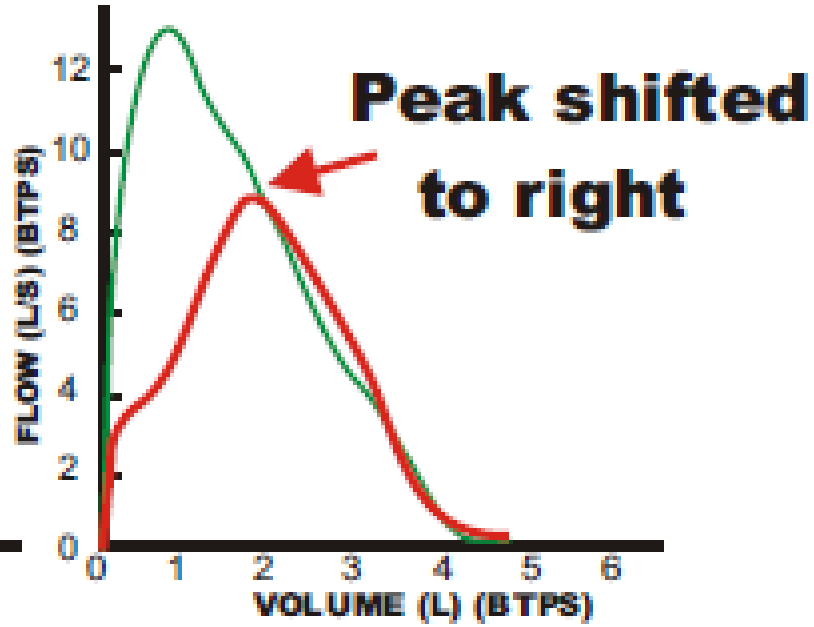


DHHS (NIOSH) Publication No. 2011-135

Hesitation; Slow Start; Large Extrapolated Volume

Delete Curve; Coach: Blast FASTER

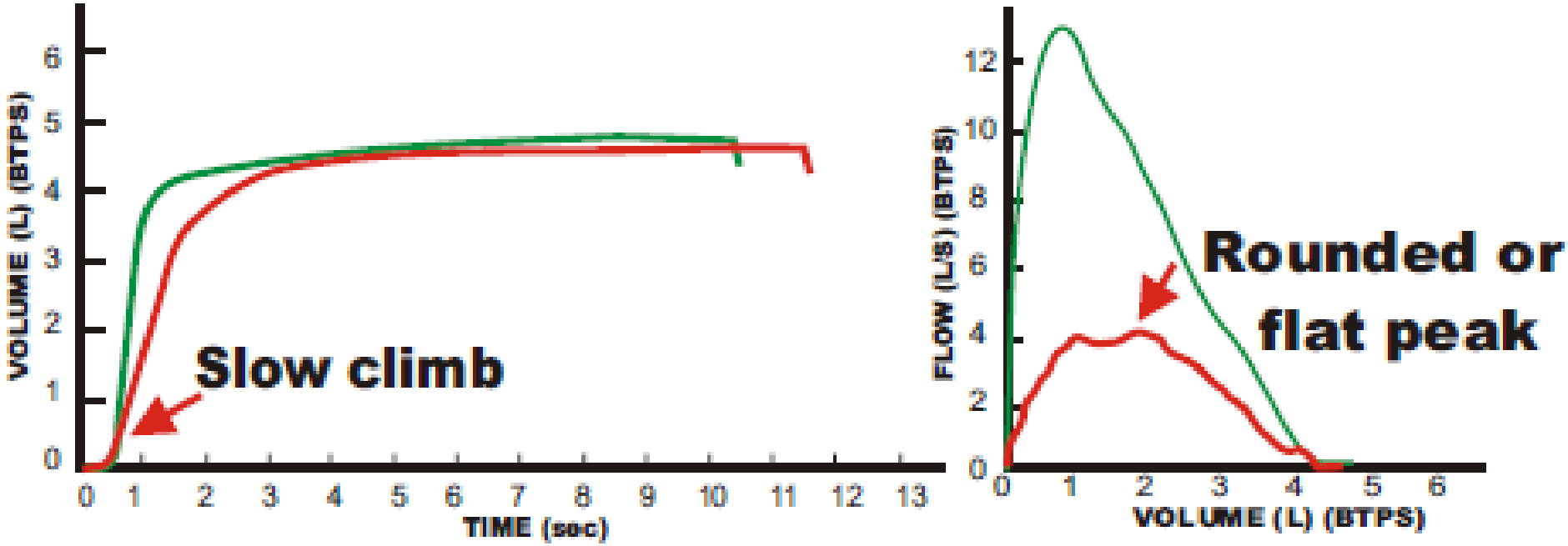




DHHS (NIOSH) Publication No. 2011-135

Poor Initial Blast

Coach: Blast air out HARDER



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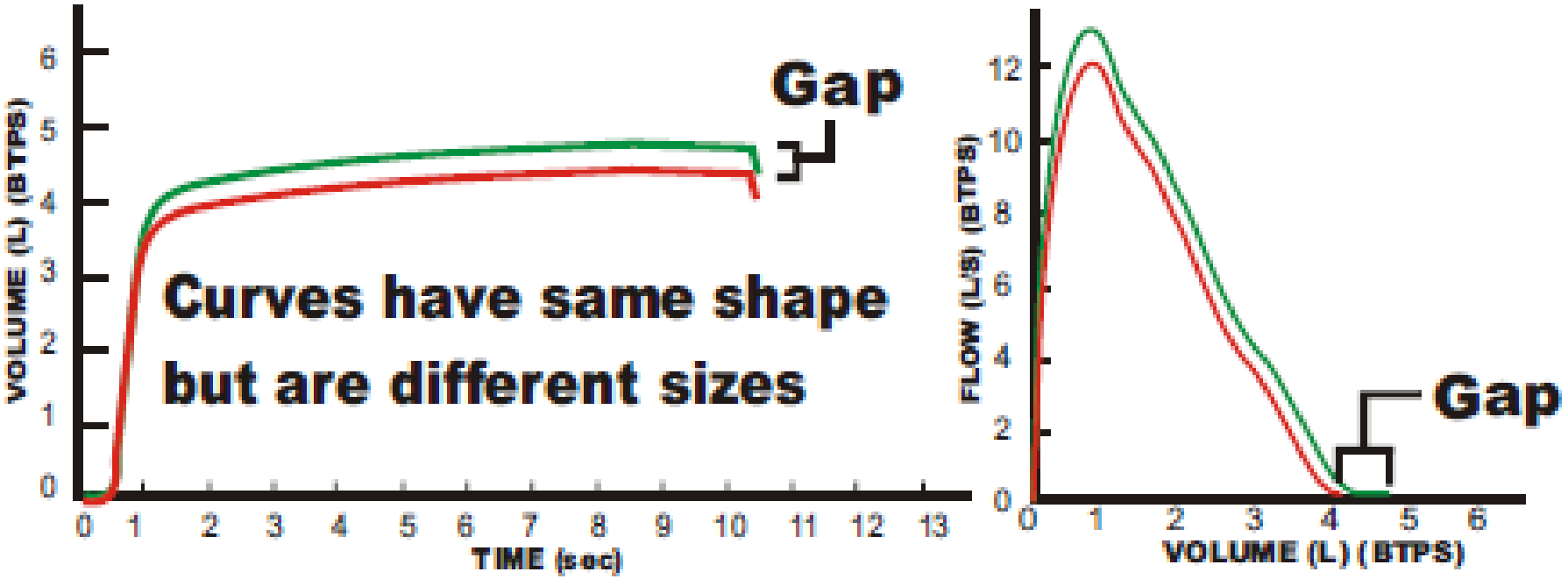
Incomplete Inhalation

Coach: Take a DEEPER breath



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Clinical Data Gathered

- Forced Vital Capacity (FVC) maneuver
- Measurements
  - FVC = forced vital capacity
  - FEV_1 = forced expiratory volume in one second
  - Ratio FEV_1/FVC
  - FET = forced expiratory time
  - Not recommended 2017 but may use in 2019*
    - FEF_{25-75} = “midflows” = MMEF (Maximal Mid-Expiratory Flows)
    - PEFR = peak expiratory flow rate
  - New in 2019
    - FIVC

FVC

- Forced Vital Capacity
- Effort dependent
- Presentation*
  - Value in liters
  - Referenced lower limit of normal
  - Referenced Z score
  - Referenced % predicted (mean)
  - Do not present the predicted (mean) value

Am J Respir Crit Care Med 2017;196: 1463-1472.

2017 ATS Reporting Standards

SPIROMETRY

	Pre-Bronchodilator				Post-Bronchodilator				
	Best	LLN	z-score	%Pred	Best	z-score	%Pred	Change	%Chng
FVC (L)	**3.90**	3.70	–1.34	82%					
FEV1 (L)	**2.02**	2.91	–3.78	54%					
FEV1/FVC	**0.52**	0.68	–3.54						
FET (s)	**10.3**								

Reference values: GLI 2012 Test quality: Pre: FEV1 - A, FVC - A; Post: FEV1 - A, FVC - B

Am J Respir Crit Care Med 2017;196: 1463-1472.

FEV_1

- Forced expiratory volume in one second
- Effort dependent
- Presentation*
  - Value in liters
  - Referenced lower limit of normal
  - Referenced Z score
  - Referenced % predicted (mean)
  - Do not present the predicted (mean) value

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FEV_1/FVC Ratio

- Not an independent test - simply mathematical relationship
- Presentation*
  - Presented ONLY as an absolute ratio (ie 0.72)
  - Do not present as % (not 72%)
  - Referenced lower limit of normal
  - Referenced Z score
  - Definitely do not present as % predicted (mean)

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FEV_1/FVC Ratio

- Key Factors
  - FEV_1/FVC ratio < lower limit of normal indicates and defines an obstructive pattern
  - Most sensitive measure of obstruction
- Severity of obstruction is determined by FEV_1

Am J Respir Crit Care Med 2017;196: 1463-1472.

Midflows

- $FEF_{25-75\%}$
- MMEF = maximal mid expiratory flow rate
- 2017
  - Not recommended for use or in report*
  - Have not demonstrated added value for identifying obstruction in adults or children
- 2019
  - May be reported without endorsing it

Am J Respir Crit Care Med 2019;200:70-88.

Grading Adequacy

- Direct observation for proper effort
- Acceptability criteria – within each test/effort
- Reproducibility criteria – between tests/efforts

Eur Respir J 2005;26:948-68.

Grading Adequacy

- Acceptability
  - Examination of tracing and values within maneuver
  - A good start - no hesitation (extrapolated volume criteria available)
  - Sharp rise in peak flow
    - Rise from 10% to 90% PEF should be ≤150 milliseconds
    - Within first 25% of FVC (not ATS)
  - Flow/volume loop smooth without notching or artifact
    - No early cough
    - No early termination/glottic closure
  - Adequate duration when end of forced expiration (EOFE) – not end of test (EOT)
    - No change in volume (<0.025 L) for >1 second (plateau in VT curve)
    - Effort is > 15 sec
    - No minimum time (no longer ≥ 3 sec in children and ≥ 6 sec in adults)
  - FIVC – FVC ≤ 0.100 L or 5% of FVC – whichever is greater

Eur Respir J 200526:948-68.
Am J Respir Crit Care Med 2019;200:70-88.

Grading Adequacy

- Reproducibility
  - Comparison between maneuvers
  - 3 acceptable spirograms
  - FVC and FEV1 graded independently
  - 2 best FVC and FEV1 measures
    - Within 0.150 L of each other for > 6 yo
    - Within 0.100 L or 10% of largest FVC whichever greater for $\leq$ 6 yo

Eur Respir J 2005;26:948-68.
Am J Respir Crit Care Med 2017;196: 1463-1472.

2017 Grading Adequacy

Table 1. Quality Categories for FVC or FEV_1 in Adults and Children

Grade	Criteria for Adults and Older Children and for Children Aged 2–6 Years
A	⩾3 acceptable tests with repeatability within 0.150 L for age 2–6, 0.100 L, or 10% of highest value, whichever is greater
B	⩾2 acceptable tests with repeatability within 0.150 L for age 2–6, 0.100 L, or 10% of highest value, whichever is greater
C	⩾2 acceptable tests with repeatability within 0.200 L for age 2–6, 0.150 L, or 10% of highest value, whichever is greater
D	⩾2 acceptable tests with repeatability within 0.250 L for age 2–6, 0.200 L, or 10% of highest value, whichever is greater
E	One acceptable test
F	No acceptable tests

- Clinically useful = Grades A, B, C
- Should not use = Grades D, E, F

Am J Respir Crit Care Med 2017;196: 1463-1472.

2019 Grading Adequacy

Grade	Number of Measurements	Repeatability: Age >6 yr	Repeatability: Age ≤6 yr*
A	≥3 acceptable	Within 0.150 L	Within 0.100 L*
B	2 acceptable	Within 0.150 L	Within 0.100 L*
C	≥2 acceptable	Within 0.200 L	Within 0.150 L*
D	≥2 acceptable	Within 0.250 L	Within 0.200 L*
E	≥2 acceptable	>0.250 L	>0.200 L*
	OR 1 acceptable	N/A	N/A
U	0 acceptable AND ≥1 usable	N/A	N/A
F	0 acceptable and 0 usable	N/A	N/A

Definition of abbreviation: N/A = not applicable.
The repeatability grade is determined for the set of prebronchodilator maneuvers and the set of post-bronchodilator maneuvers separately. The repeatability criteria are applied to the differences between the two largest FVC values and the two largest FEV_1 values. Grade U indicates that only usable but not acceptable measurements were obtained. *Although some maneuvers may be acceptable or usable at grading levels lower than A, the overriding goal of the operator must be to always achieve the best possible testing quality for each patient.* Adapted from Reference 114.
*Or 10% of the highest value, whichever is greater; applies for age 6 years or younger only.

- Always strive for grade A
- Other results may still contain useful data

Am J Respir Crit Care Med 2019;200:70-88.

Assessment of Normal Values

- Comparison with “normal/healthy” subjects
- Anthropomorphically similar
  - Birth Sex
  - Age (years to one decimal place)
  - Height
  - Ethnicity – should include Caucasian, African American, NE Asian, SE Asian, Mixed or Other *
- All parameters from the same reference pool
  - Global Lung Function Initiative (GLI) – 2012 (Quanjer 2012) *

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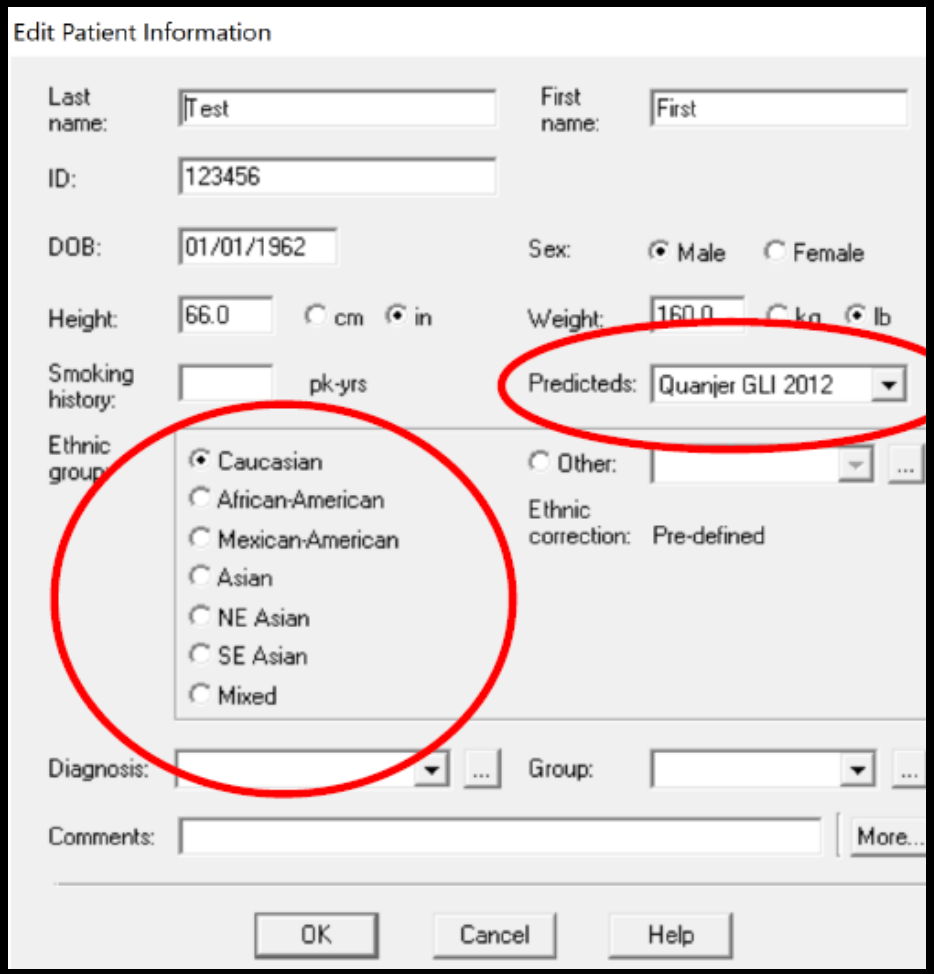
Reference Pools



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FEV1/FVC	**0.52**	0.68	–3.54		**0.55**	–3.35			
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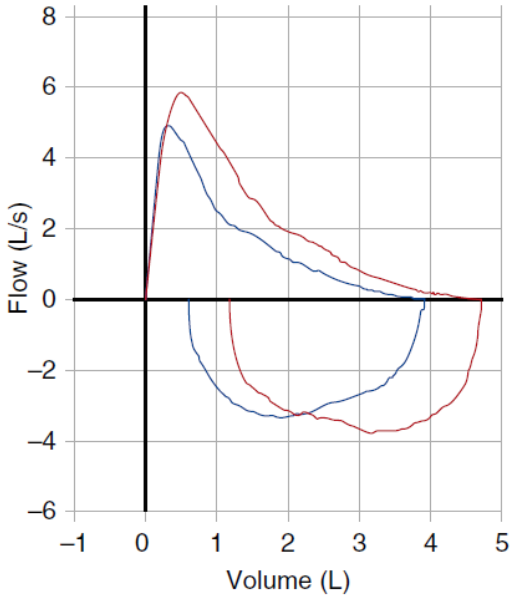

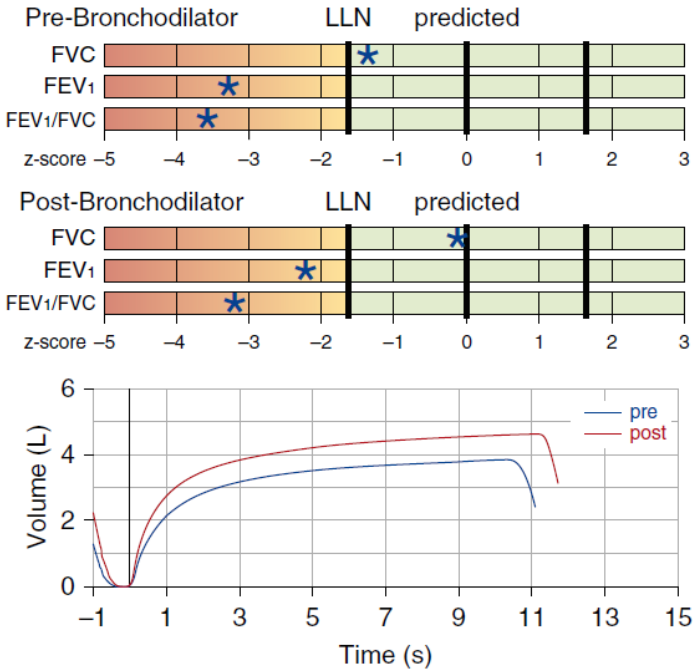

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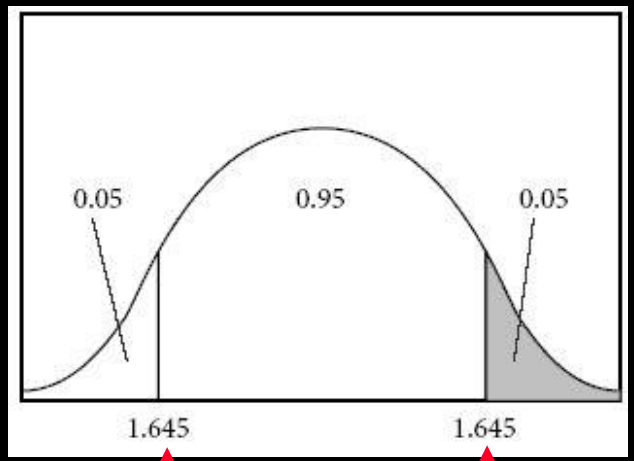
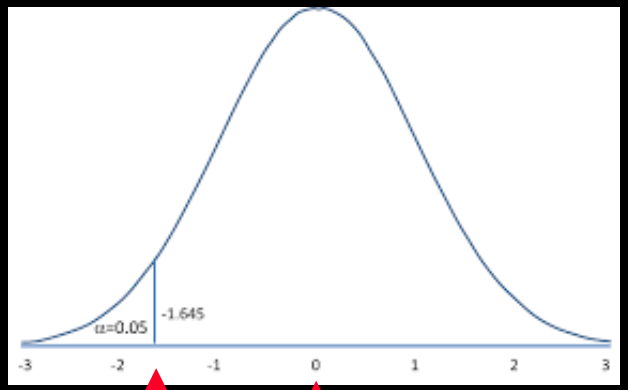
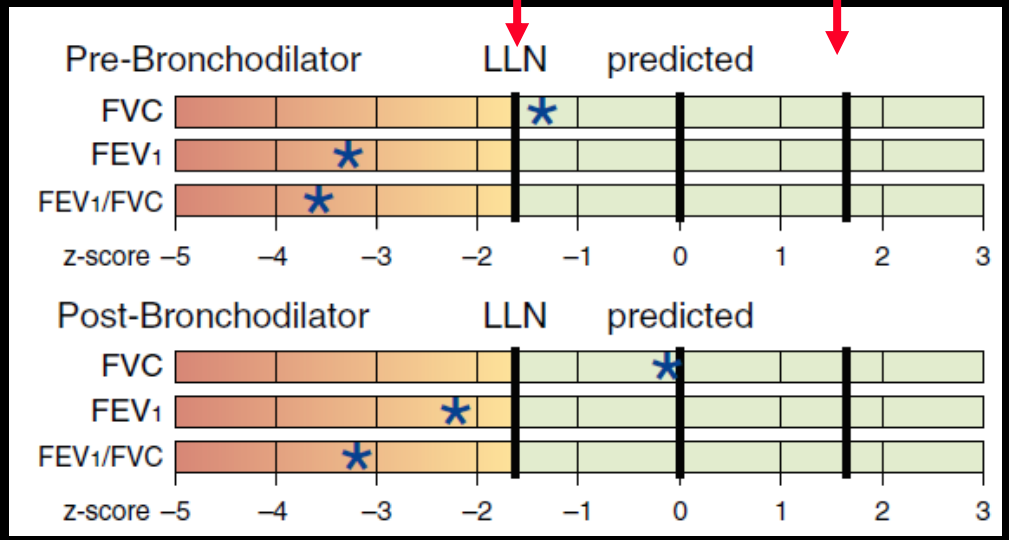
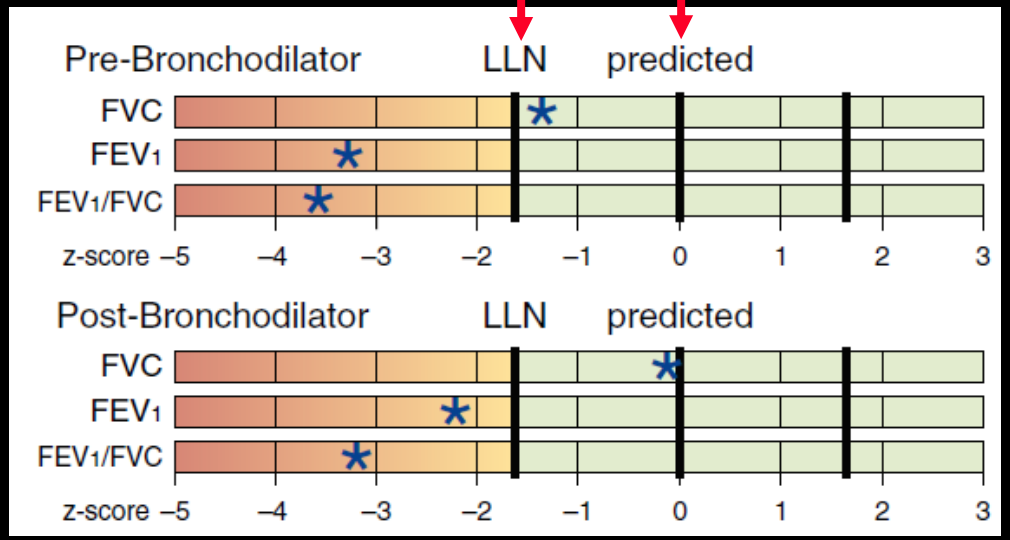
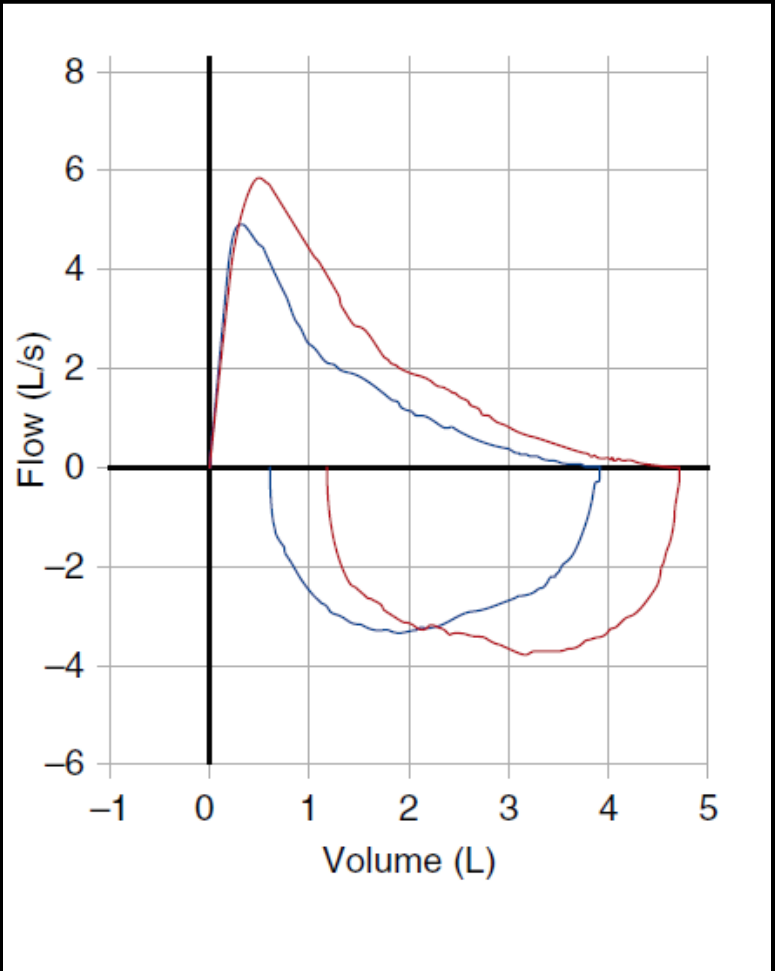


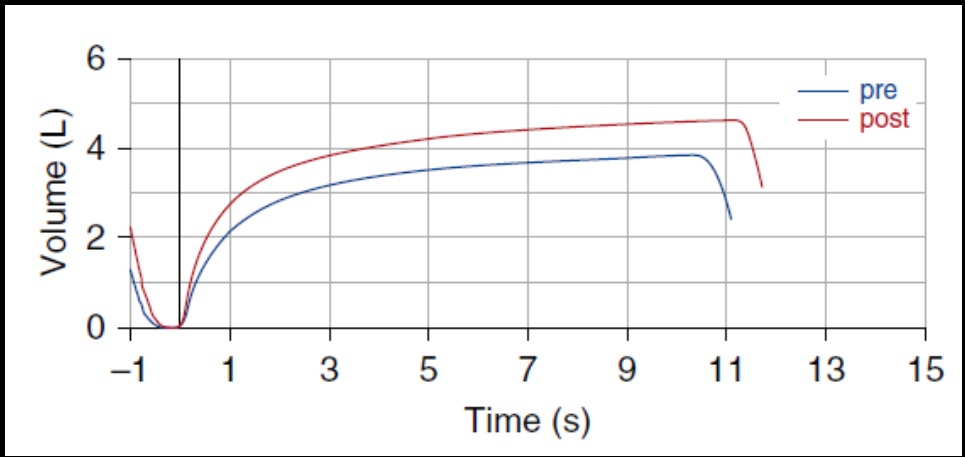






2017 ATS Reporting Standards





Am J Respir Crit Care Med 2017;196: 1463-1472.

Interpretation

- Comment on quality of test and effort
  - Less than optimal may still contain useful data
  - Identify the problem, direction and magnitude of possible error
- Comparisons
  - Reference values from healthy subjects
  - Known disease or physiologic patterns
  - Self (changes over time)
- Answer clinical question posed or that prompted test

Eur Respir J 2005;26:948-68.

Approach to Evaluation

- Epidemiologically and specialty based bias puts us generally on the hunt for obstructive lung disease
- Begin with the most sensitive and a defining measure of obstructive lung disease
- Begin with FEV1/FVC
- Determine if above or below LLN
  - Do not use “preset” cut off (ie 0.7)

Eur Respir J 2005;26:948-68.
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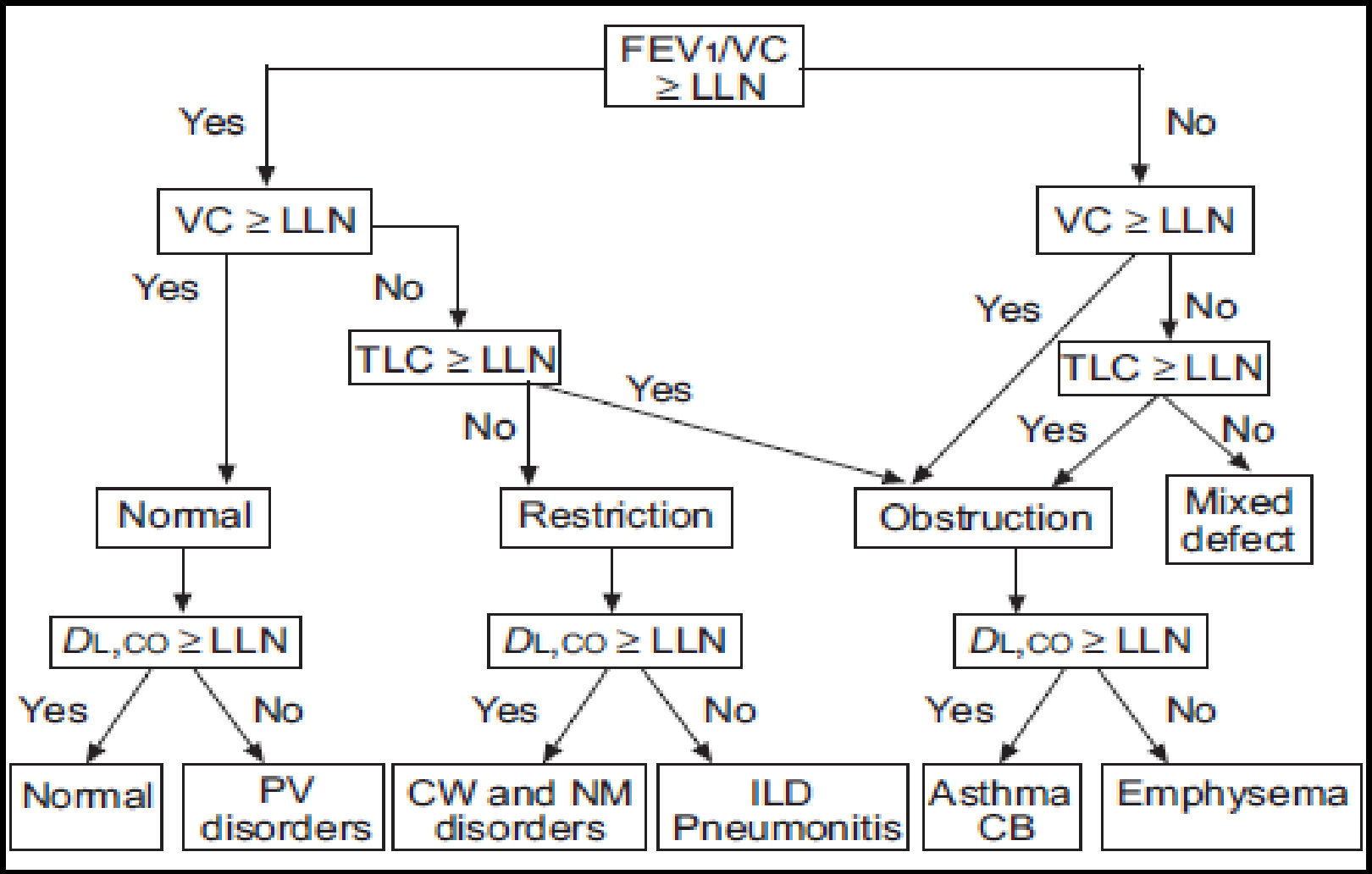
Approach to Evaluation

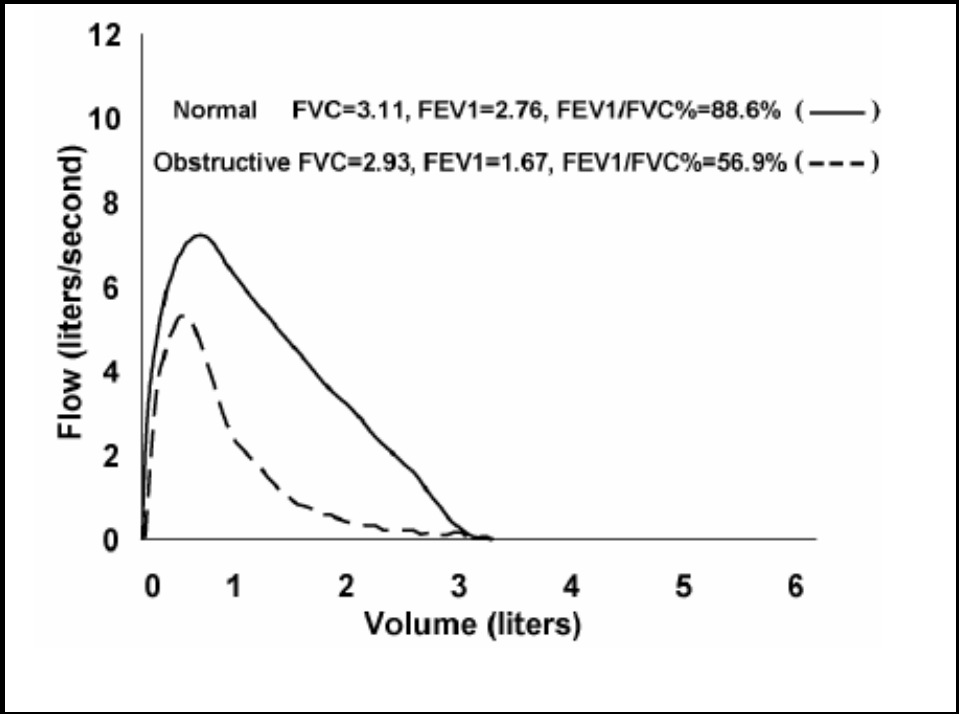


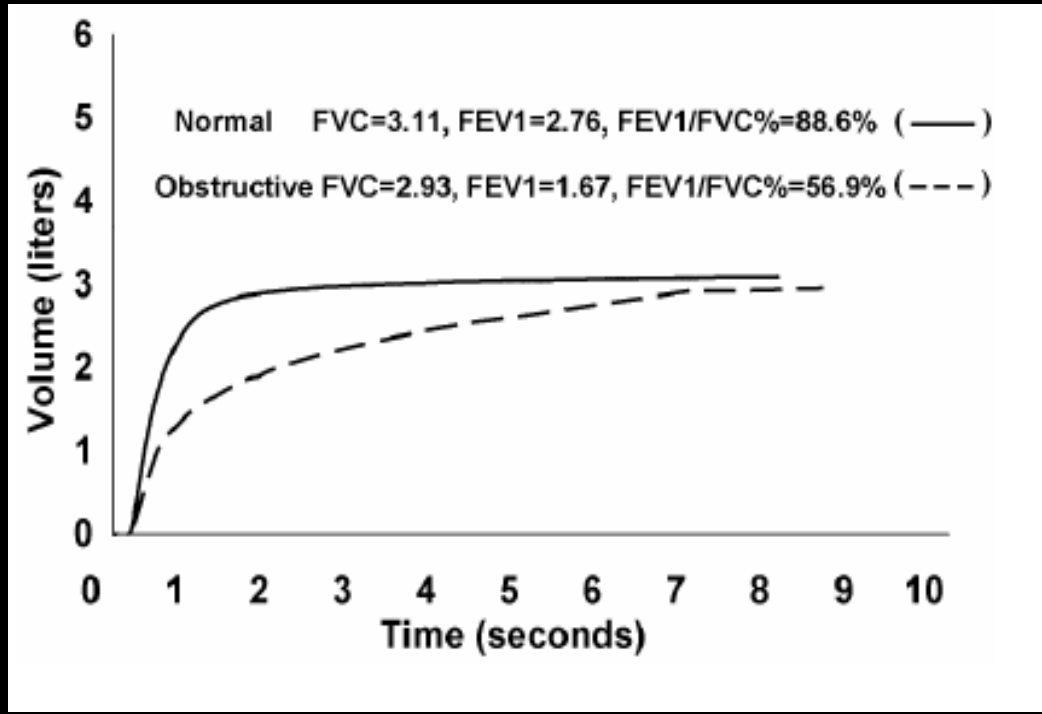
Eur Respir J 2005;26:948-68.

Obstructive Abnormalities

- Disproportionate reduction in maximal airflow (FEV_1) in relation to the maximal volume (VC)
- Implies airway narrowing
- Defined by FEV_1/VC ratio below LLN
- Earliest changes are slowing in terminal portion of spirogram leading to concave shape “scooping”

Obstructive Abnormalities





NIOSH Spirometry Training Guide - cdc.gov/niosh/

Severity Classification

TABLE 6 Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV_1)

Degree of severity	FEV_1 % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

% pred: % predicted.

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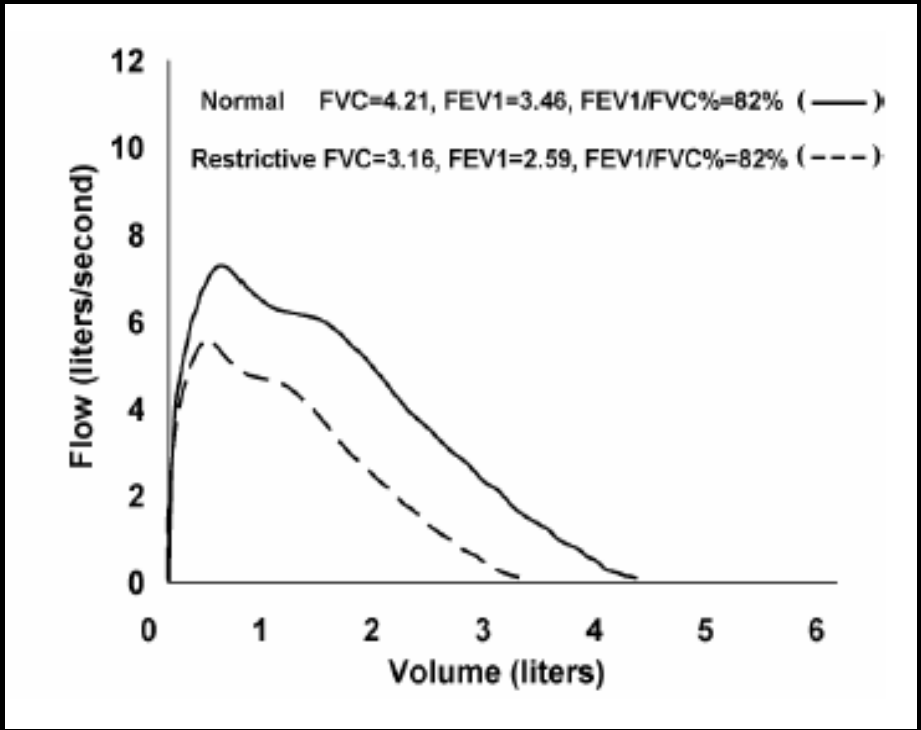
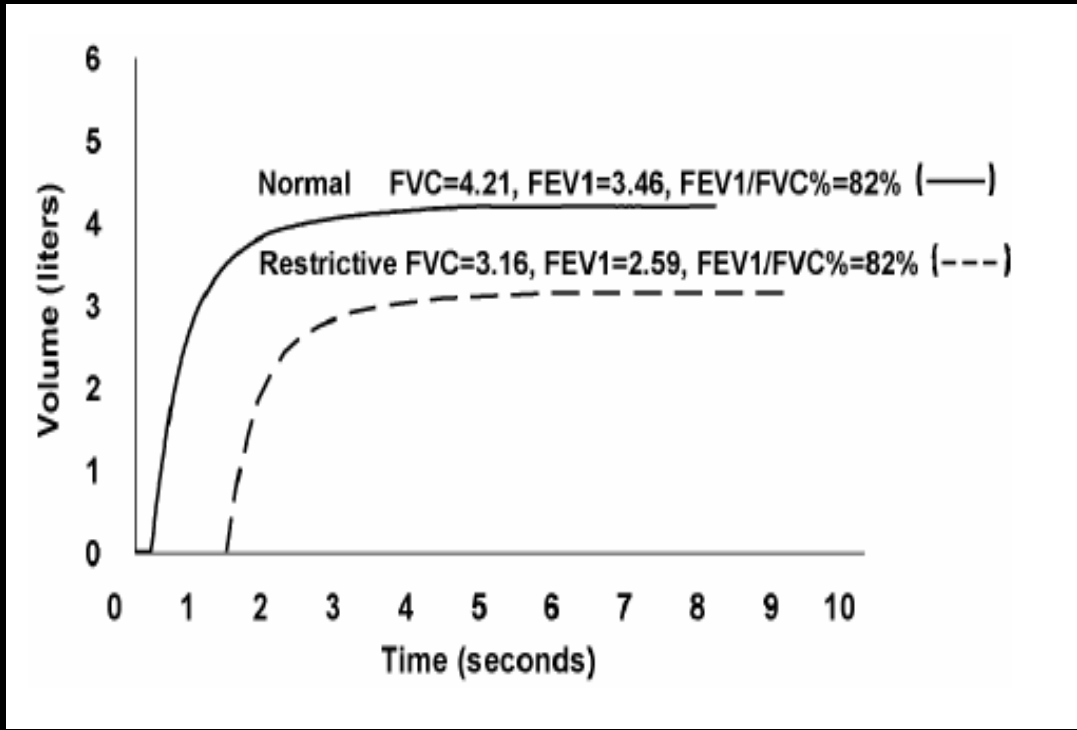
Restrictive Abnormalities

- Definition
  - TLC below LLN (5th percentile, 80%?)
  - Normal FEV1/VC
- Spirometry
  - Reduced FVC
  - Normal or increased FEV1/FVC
  - Convex pattern to FV loop
- Spirometry can be misleading – need lung volumes
  - Effort
  - Obstruction with air trapping
  - Pattern is associated with low TLC only ~ 50% time

Restrictive Abnormalities





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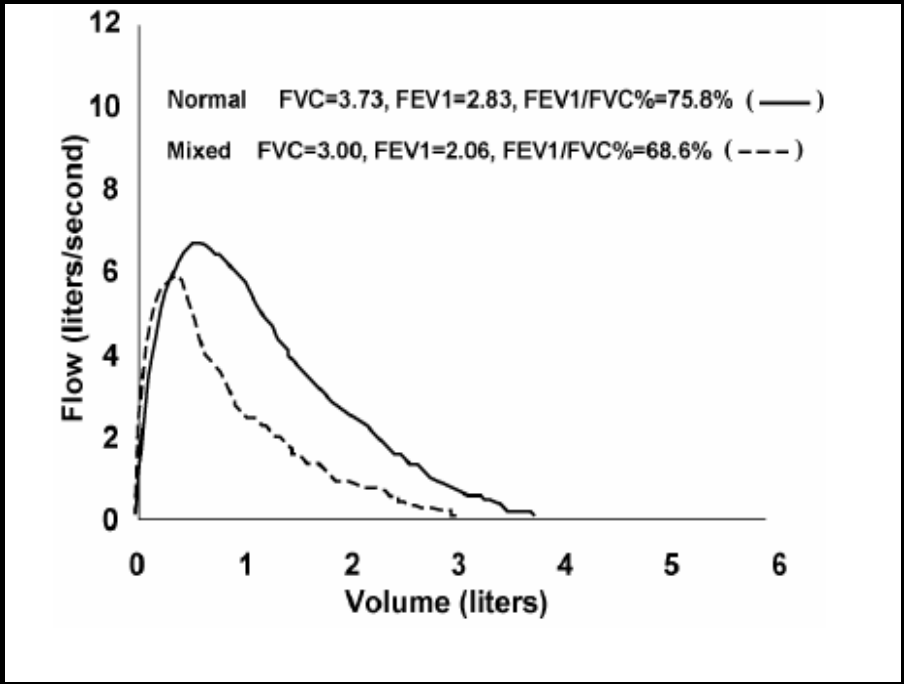
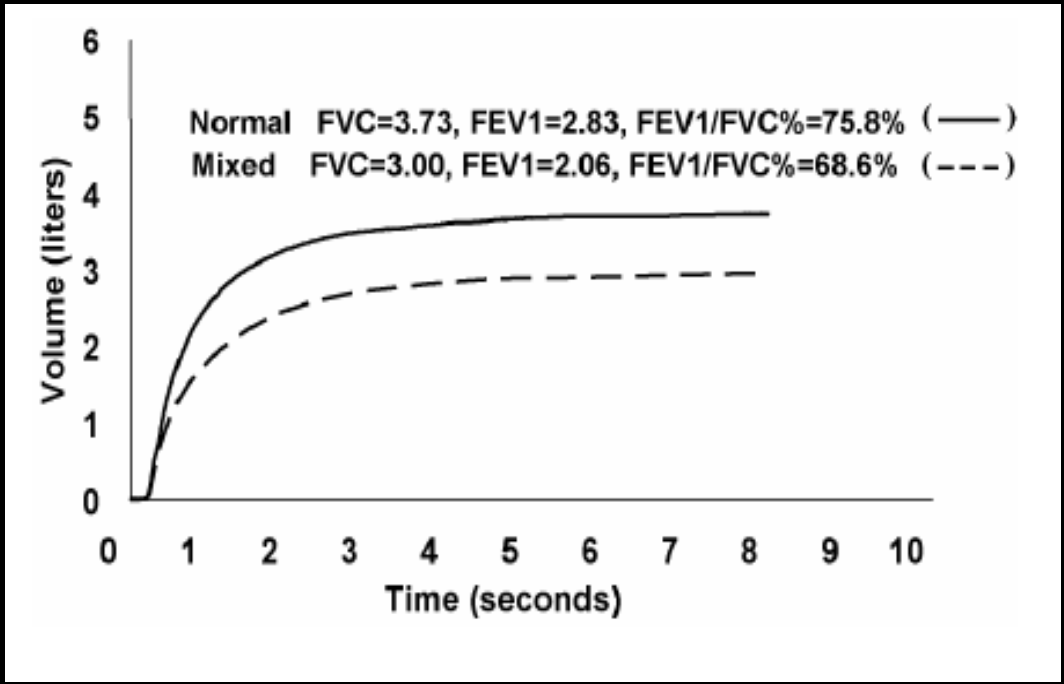
Mixed Abnormalities

- Coexisting restriction and obstruction
- Defined by abnormally reduced FEV1/VC and low TLC

Mixed Abnormalities



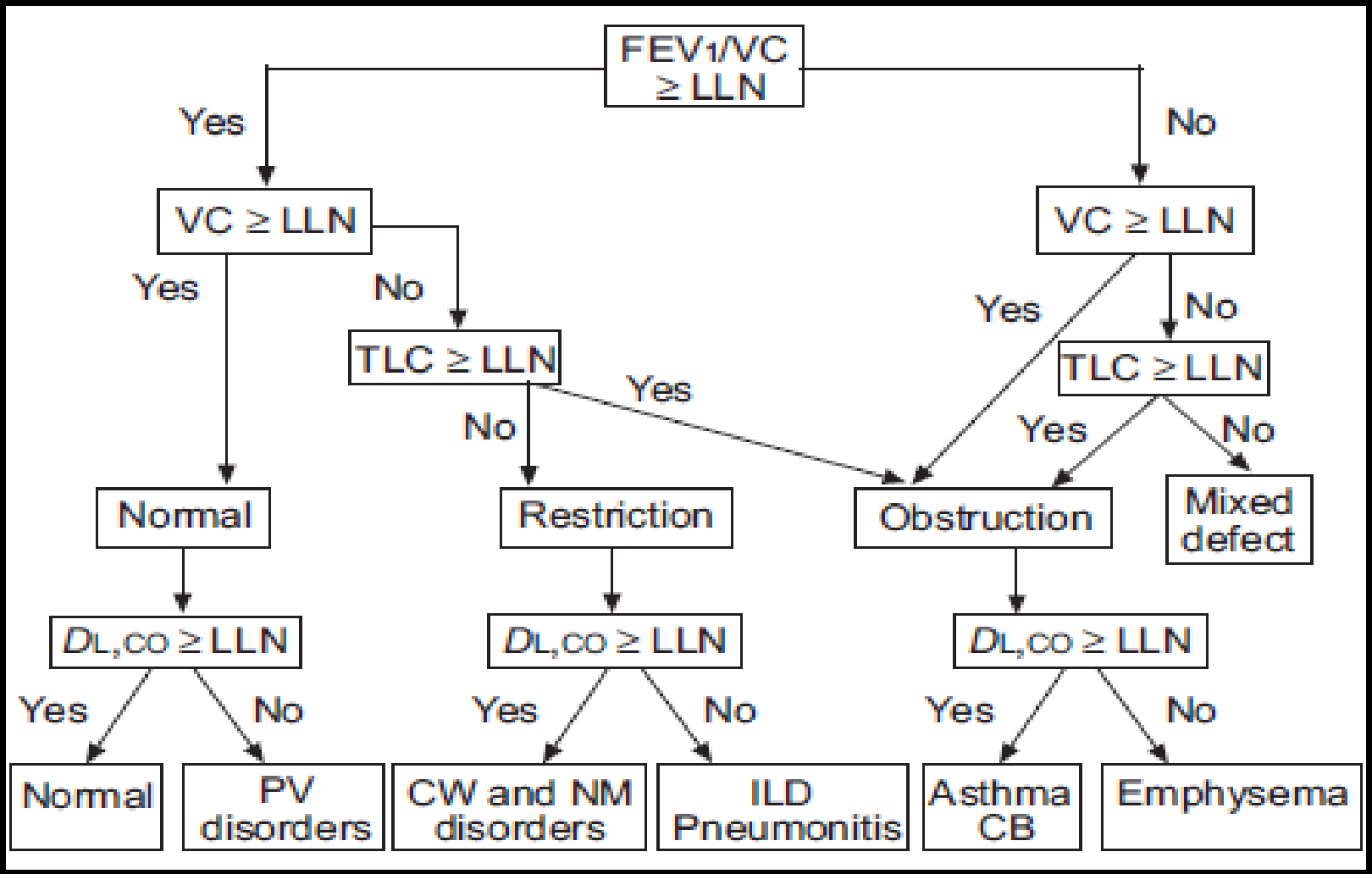


Grading Adequacy

- Acceptability
  - Examination of tracing and values within maneuver
  - A good start - no hesitation (extrapolated volume criteria available)
  - Sharp rise in peak flow
    - Rise from 10% to 90% PEF should be $\leq$150 milliseconds
    - Within first 25% of FVC (not ATS)
  - Flow/volume loop smooth without notching or artifact
    - No early cough
    - No early termination/glottic closure
  - Adequate duration when end of forced expiration (EOFE) – not end of test (EOT)
    - No change in volume (<0.025 L) for >1 second (plateau in VT curve)
    - Effort is > 15 sec
    - Effort FVC is reproducible
    - No minimum time
  - FIVC – FVC $\leq$ 0.100 L or 5% of FVC – whichever is greater

Eur Respir J 2005;26:948-68.

Approach to Evaluation



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Summary

- Background
- Spirometry and ATS guidance
  - Performance of test
  - Interpretation
    - Determining acceptability
    - Assessment of normal
    - Reference equations
    - Approach to evaluation
    - Severity classification
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