Reviewing the 2017 ATS Updates to the 2005 ATS/ERS Guidelines: How to Perform, Interpret & Report Spirometry

Seminar # 4009

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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

Sources

- ATS/ERS sources
  - 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.
  - Recommendations for a Standardized Pulmonary Function Report– American Journal of Respiratory & Critical Care Medicine, Vol 196, 2017, 1463-1472.
  - Standardization of Spirometry 2019 Update - American Journal of Respiratory & Critical Care Medicine, Vol 200, 2019, 70-88.
  - ATS website = https://www.thoracic.org/statements/pulmonary-function.php

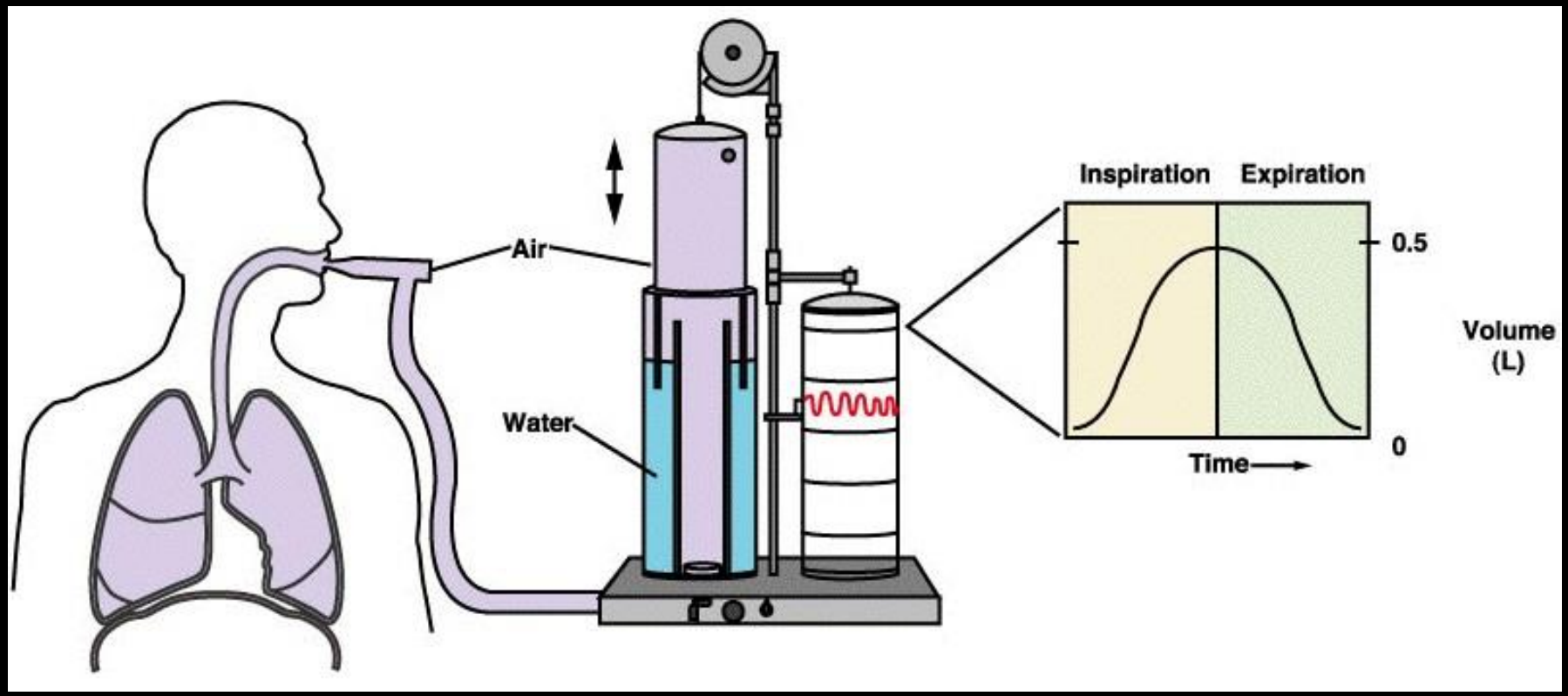
Learning Objectives

- 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

Overview

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

Instrumentation



http://respiratorysystema.blogspot.com

Subject → **Transducer** → **Signal Processing** → **Display**

Instrumentation

Subject → **Transducer** → **Signal Processing** → **Display**

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

Instrumentation

Table 3. Equipment Quality Assurance (for Both Volume- and Flow-based Sensors)

Spirometer

- Daily calibration verification at low, medium, and high flow: If the calibration verification fails, check for and remediate problems (Table 4) and repeat calibration verification
- If an in-line filter is used in spirometry testing, then it must also be used during recalibrations and verifications
- Recalibrate the spirometer both after failed calibration verification and at intervals specified by the manufacturer
- If the change in calibration factor is ⩾6% or varies by more than ±2 SD from the mean, inspect and, if necessary, clean the spirometer according to the manufacturer's instructions; check for errors (Table 4) and recalibrate the spirometer
- Perform routine checks and maintenance at intervals specified by the manufacturer

3-L calibration syringe

- Daily inspection for displacement of the piston stop
- Daily check for smooth operation of the syringe with no sticking or catching
- Accuracy of ±0.015 L verified by manufacturer on delivery and at intervals recommended by the manufacturer
- Monthly syringe leak test

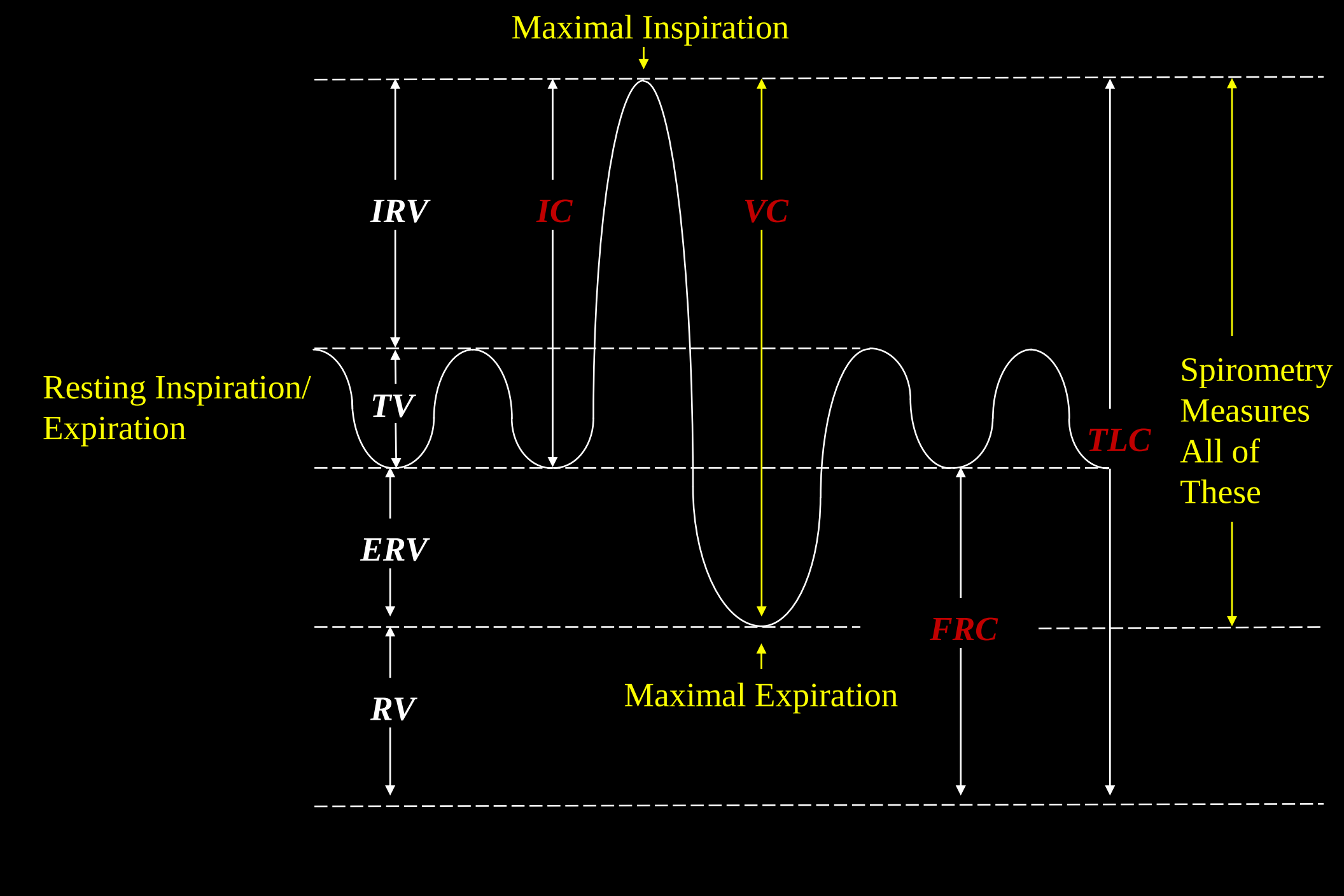
Documentation

- A log of all quality control findings, repairs and adjustments, and hardware and software updates
- Verification of reference value calculations after software updates

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

Basic Defintions

- 4 Lung volumes - cannot be further subdivided
  - Tidal volume (TV)
  - Inspiratory reserve volume (IRV)
  - Expiratory reserve volume (ERV)
  - Residual volume (RV)
- 4 Lung capacities - composed of 2 or more volumes
  - Total lung capacity (TLC)
  - Vital capacity (VC)
  - Inspiratory capacity (IC)
  - Functional residual capacity (FRC)


Maximal Inspiration
IRV
IC
VC
TLC
Resting Inspiration/
Expiration
TV
Spirometry
Measures
All of
These
ERV
FRC
Maximal Expiration
RV

Indications

Diagnosis
- To evaluate symptoms, signs, or abnormal laboratory test results
- To measure the physiologic effect of disease or disorder
- To screen individuals at risk of having pulmonary disease
- To assess preoperative risk
- To assess prognosis

Monitoring
- To assess response to therapeutic intervention
- To monitor disease progression
- To monitor patients for exacerbations of disease and recovery from exacerbations
- To monitor people for adverse effects of exposure to injurious agents
- To watch for adverse reactions to drugs with known pulmonary toxicity

Disability/impairment evaluations
- To assess patients as part of a rehabilitation program
- To assess risks as part of an insurance evaluation
- To assess individuals for legal reasons

Other
- Research and clinical trials
- Epidemiological surveys
- Derivation of reference equations
- Preemployment and lung health monitoring for at-risk occupations
- To assess health status before beginning at-risk physical activities

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

Contraindications

Due to increases in myocardial demand or changes in blood pressure
- Acute myocardial infarction within 1 wk
- Systemic hypotension or severe hypertension
- Significant atrial/ventricular arrhythmia
- Noncompensated heart failure
- Uncontrolled pulmonary hypertension
- Acute cor pulmonale
- Clinically unstable pulmonary embolism
- History of syncope related to forced expiration/cough

Due to increases in intracranial/intraocular pressure
- Cerebral aneurysm
- Brain surgery within 4 wk
- Recent concussion with continuing symptoms
- Eye surgery within 1 wk

Due to increases in sinus and middle ear pressures
- Sinus surgery or middle ear surgery or infection within 1 wk

Due to increases in intrathoracic and intraabdominal pressure
- Presence of pneumothorax
- Thoracic surgery within 4 wk
- Abdominal surgery within 4 wk
- Late-term pregnancy

Infection control issues
- Active or suspected transmissible respiratory or systemic infection, including tuberculosis
- Physical conditions predisposing to transmission of infections, such as hemoptysis, significant secretions, or oral lesions or oral bleeding

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

Performing Spirometry

- Forced Vital Capacity Maneuver
  - Maximal volume of air exhaled with maximally forced effort from a maximal inspiration
  - 4 distinct phases
    - Maximal inspiration – largest source of error is inadequate maximal inspiration
    - “Blast” of exhalation
    - Continued complete exhalation to the end of test (no volume change = <0.025 L over 1 sec) but no longer than 15 seconds – second largest source of error is ending expiration prematurely
    - Inspiration at maximal flow back to maximal lung volume

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Performing Spirometry

- Check spirometer calibration
- Preparatory instructions
  - Avoid smoking within 1 hour
  - Avoid alcohol/intoxicants within 8 hours
  - Avoid vigorous exercise within 1 hour
  - Avoid constricting clothing of chest/abdomen
  - Avoid a large meal within 2 hours
  - Avoid loose fitting dentures
- Prepare the subject
  - Ask about smoking, medication, illness, pain, etc
  - Measure standing height and weight
- Explain and demonstrate the test

Eur Respir J 2005;26:319-38.

Performing Spirometry

Table 5. Activities That Should Be Avoided before Lung Function Testing

- Smoking and/or vaping and/or water pipe use within 1 h before testing (to avoid acute bronchoconstriction due to smoke inhalation)
- Consuming intoxicants within 8 h before testing (to avoid problems in coordination, comprehension, and physical ability)
- Performing vigorous exercise within 1 h before testing (to avoid potential exercise-induced bronchoconstriction)
- Wearing clothing that substantially restricts full chest and abdominal expansion (to avoid external restrictions on lung function)

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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-motivated, enthusiastic nurse or technician is key

Eur Respir J 2005;26:319-38.

Performing Spirometry

- Inhale completely and rapidly with <1 sec pause at TLC
  - "Inhale as deeply as possible"
  - "An enormous breath in"
  - Will have raised eyebrows +/- be wide eyed +/- head quivering …. comfortable appearance likely = incomplete effort
- Exhale maximally completely until no more air can be expelled while maintaining posture
- Repeat with coaching as necessary (warn patient)
  - "Blast it out !!!" as opposed to "blow"
  - "Keep going, keep going !!!", "More, more, more !!!"
- Maximal inspiration after forced expiration = forced inspiratory vital capacity (FIVC)
- Perform minimum of 3 maneuvers, no more than 8 are usually required, except in children

Eur Respir J 2005;26:319-38.

Most Common Errors

- Lack of motivated and enthusiastic patient coaching
- Failure of patient to take a complete inhalation prior to exhalation
- Failure to request enough efforts from the subject to acquire their best effort
- Patient stops exhaling too soon
- Patient obstructed mouthpiece with teeth or tongue
- Slow test start = patient didn't "blast" the air out at the beginning of the test
- Patient coughed during test

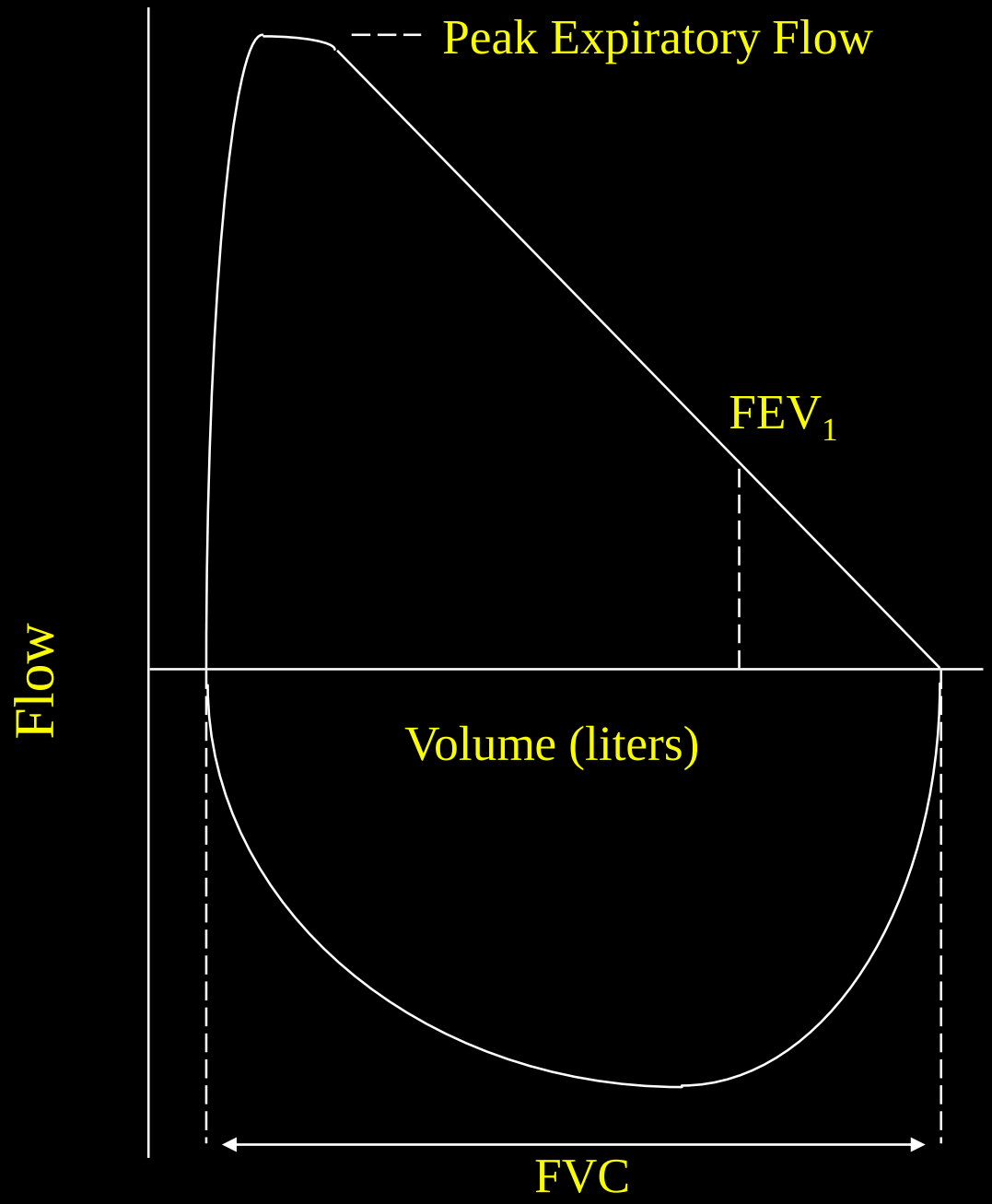
Eur Respir J 2005;26:319-38.

Clinical Data Gathered

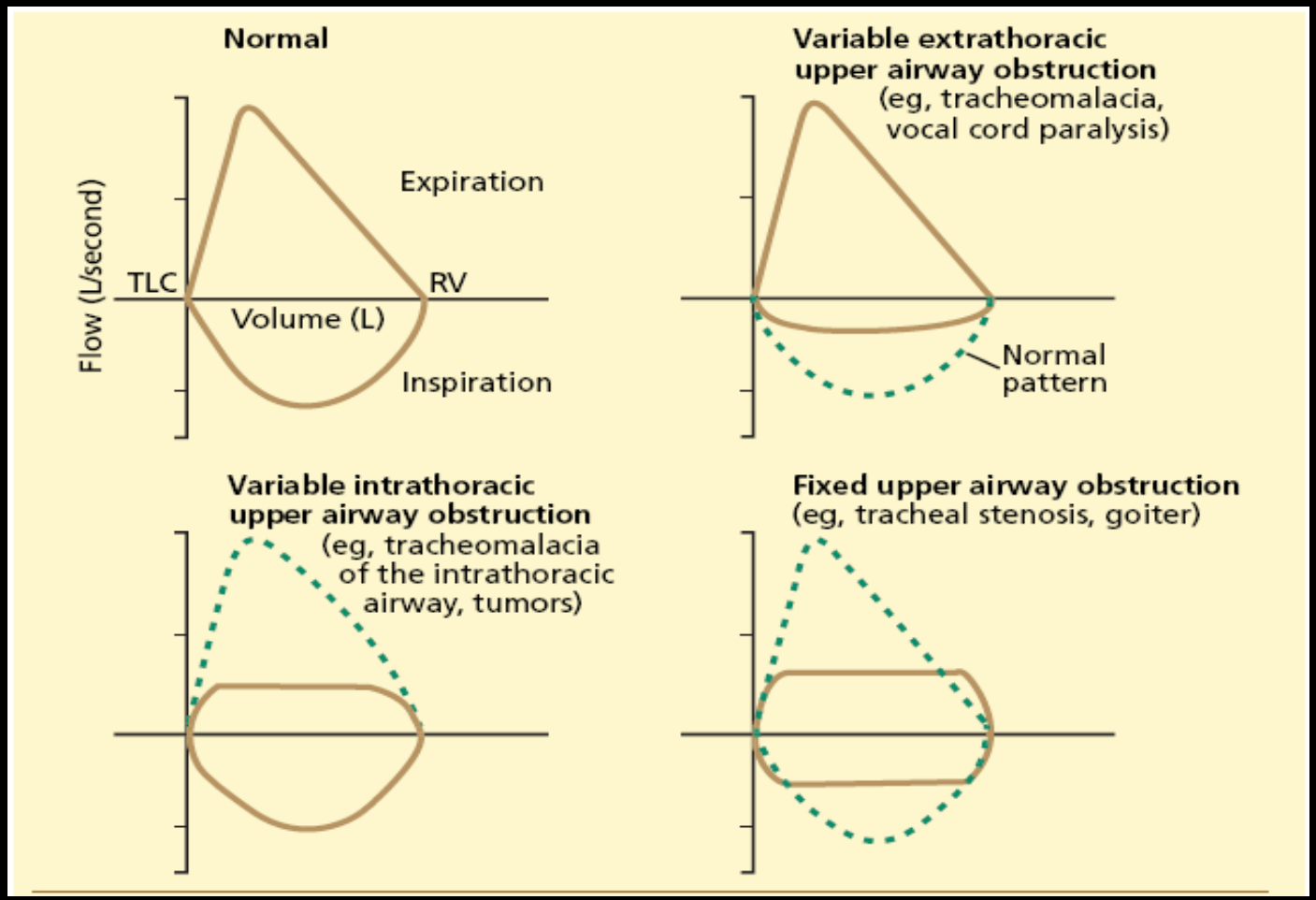
- Forced Vital Capacity (FVC) maneuver
- Graphic displays
  - Flow Volume Loop
  - Volume vs time curve
- Measurements
  - FVC = forced vital capacity
  - FEV_1 = forced expiratory volume in one second
  - Ratio FEV_1/FVC
  - FET = forced expiratory time
  - Not recommended*
    - FEF_{25-75} = “midflows” = MMEF (Maximal Mid-Expiratory Flows)
    - PEFR = peak expiratory flow rate

Flow-Volume Loops

- Recognition of characteristic patterns of abnormalities
- Recognition of poor effort or mistakes by patient that make absolute numbers unreliable
- Directly determine peak flow
- Directly determine FVC


Peak Expiratory Flow
FEV1
Flow
Volume (liters)
FVC

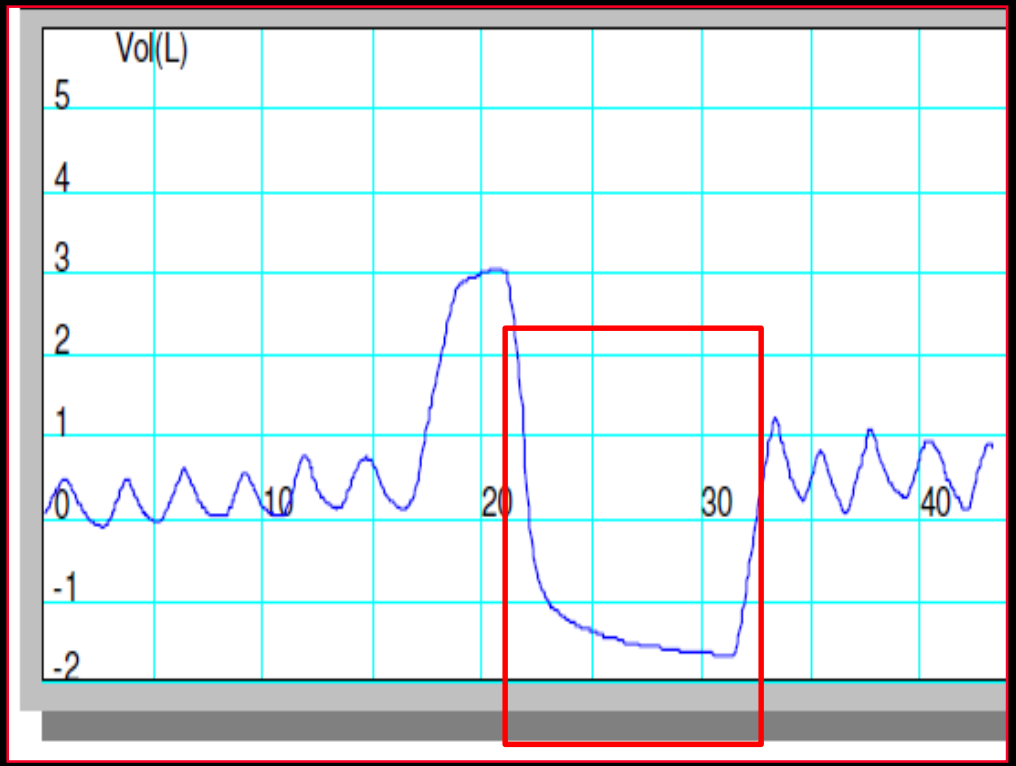
Flow-Volume Loops: Patterns

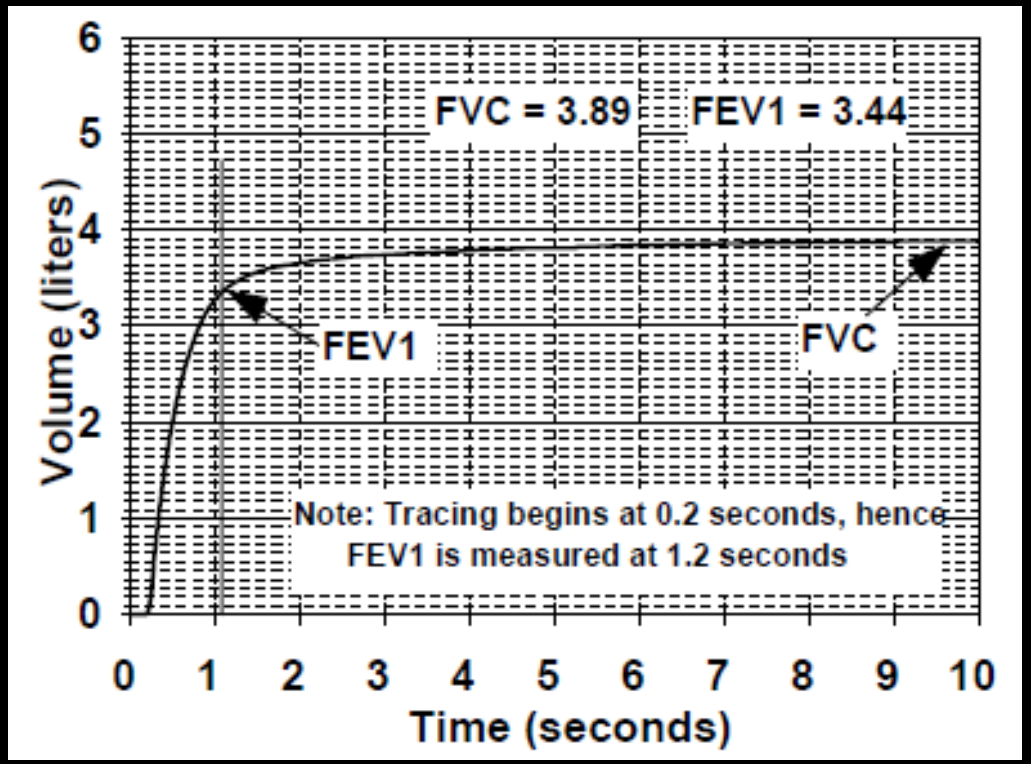


Volume vs Time Curve

- Recognition of characteristic patterns of abnormalities
- Recognition of duration of test and timing of events that make absolute numbers unreliable
- Directly determine FEV1
- Directly determine total expiratory time (TET)
- Directly determine FVC

Volume vs Time Curve





NIOSH Spirometry Training Guide - cdc.gov/niosh/

FVC

- Forced Vital Capacity
- Full inspiration to total lung capacity
- Rapid, forceful, maximal expiration
- Effort dependent
- Presentation*
  - Value in liters
  - Referenced lower limit of normal
  - Referenced Z score
  - Referenced % predicted
  - Do not present the predicted value

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

FEV_1

- Based on FVC maneuver
- Forced expiratory volume in one second
- Volume expired in the first second
- Effort dependent
- Presentation*
  - Value in liters
  - Referenced lower limit of normal
  - Referenced Z score
  - Referenced % predicted
  - Do not present the predicted value

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FEV_1/FVC Ratio

- Not an independent test - simply mathmatical relationship
- Presentation*
  - Presented as an absolute ratio (ie 0.72)
  - ONLY use the absolute ratio
  - Do not present as % (not 72%)
  - Referenced lower limit of normal
  - Referenced Z score
  - Definitely do not present as % predicted
- Key Factors
  - FEV_1/FVC ratio < lower limit of normal indicates 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

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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) *
  - Can continue Hankinson (NHANES III) if continuity important

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

Grading Adequacy

- Direct observation for proper effort
- Acceptability criteria
- Reproducibility criteria

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
    - Effort FVC is reproducible
    - No minimum time
  - FIVC – FVC ≤ 0.100 L or 5% of FVC – whichever is greater

Eur Respir J 2005;26:948-68.

Grading Adequacy

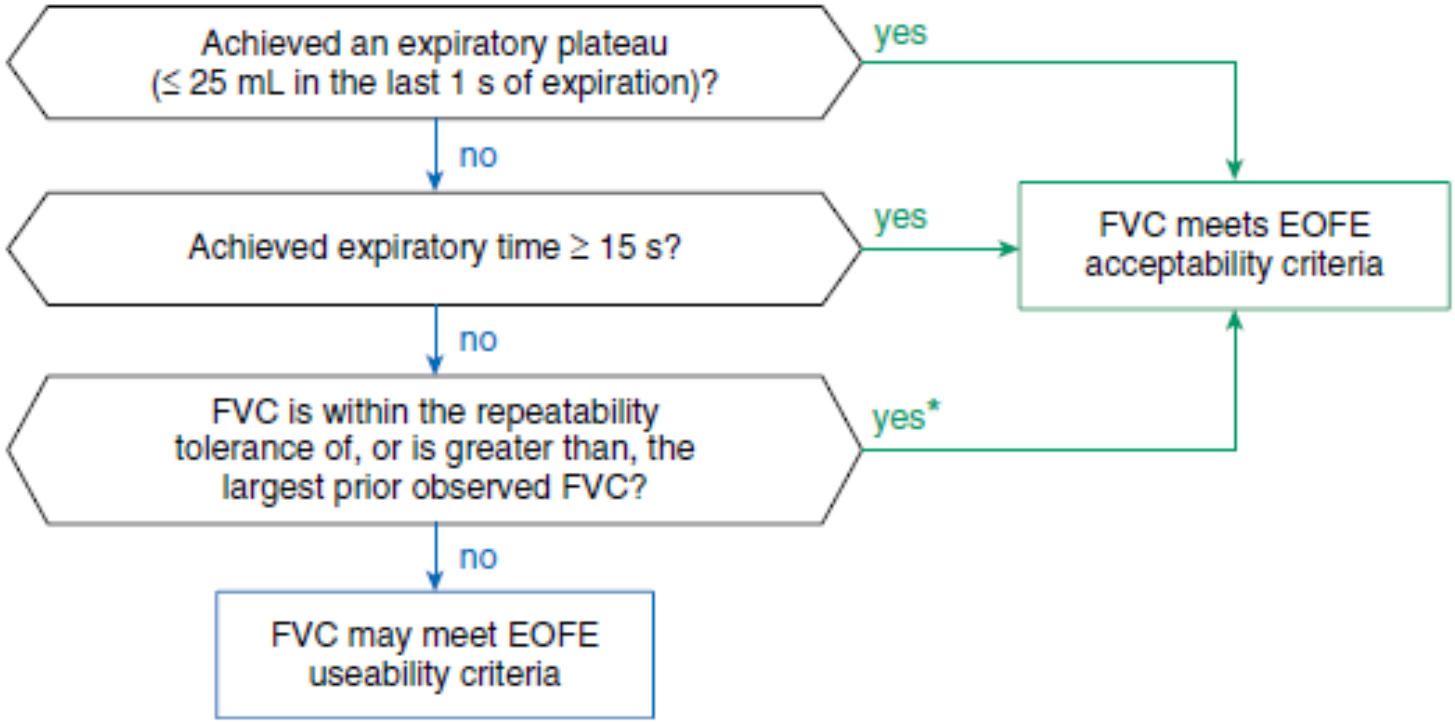


Figure 2. Flowchart outlining the end of forced expiration (EOFE) acceptability criteria for FVC. *If there are no prior observed FVC values in the current pre- or post-bronchodilator testing set, then the FVC provisionally meets EOFE acceptability criteria.

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

Grading Adequacy

- Reproducibility
  - Comparison between maneuvers
  - 3 acceptable spirograms
  - 2 best FVC and FEV1 measures
    - Within 0.150 L of each other for > 6 yo
    - Witihin 0.100 L or 10% of largest FVC whichever is greater for ≤ 6 yo
- Grading Criteria*
  - Provide feedback to technician & identifies limitations that may impact interpretation of results
  - Can be used manually or as part of spirometry software
  - Grade FEV1 and FVC separately
  - Grading system consists of ATS/ERS acceptability and reproducibility guidelines

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.

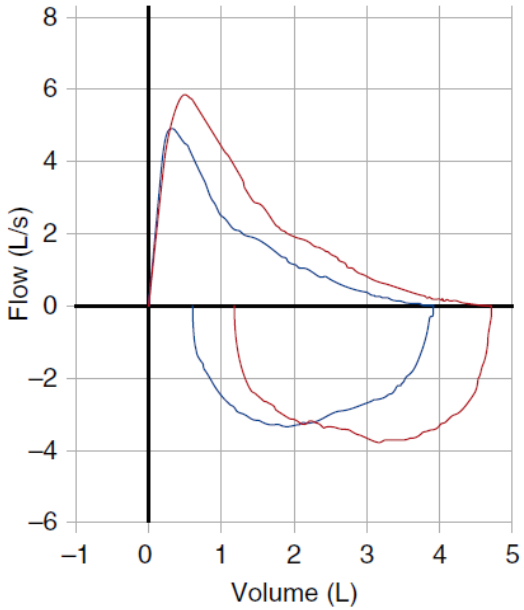
- Always strive for grade A
- Other results may still contain useful data

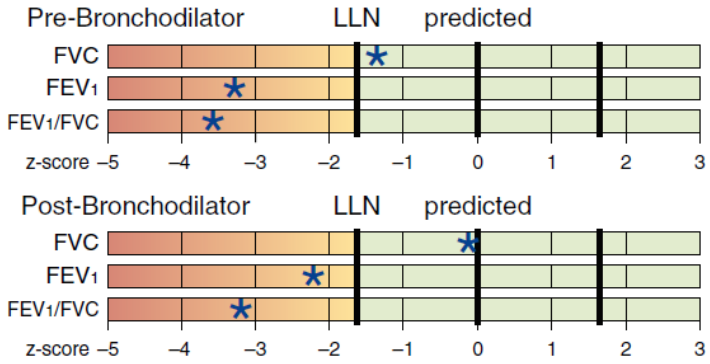
Am J Respir Crit Care Med 2019;200:70-88.

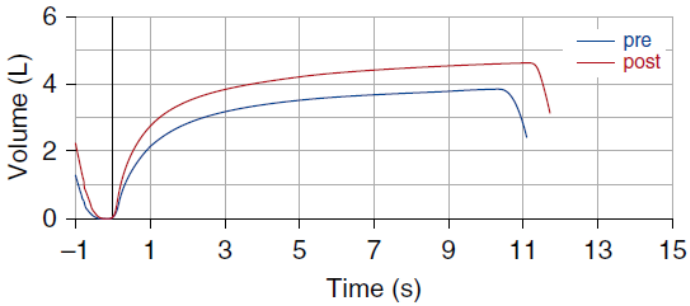
2017 ATS Reporting Standards

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%	**4.70**	–0.09	99%	600 mL	20%
FEV1 (L)	**2.02**	2.91	–3.78	54%	**2.61**	–2.21	70%	590 mL	29%
FEV1/FVC	**0.52**	0.68	–3.54		**0.55**	–3.35			
FET (s)	**10.3**				**11.2**				
Reference values: GLI 2012 Test quality: Pre: FEV1 - A, FVC - A; Post: FEV1 - A, FVC - B									







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2017 ATS Reporting Standards

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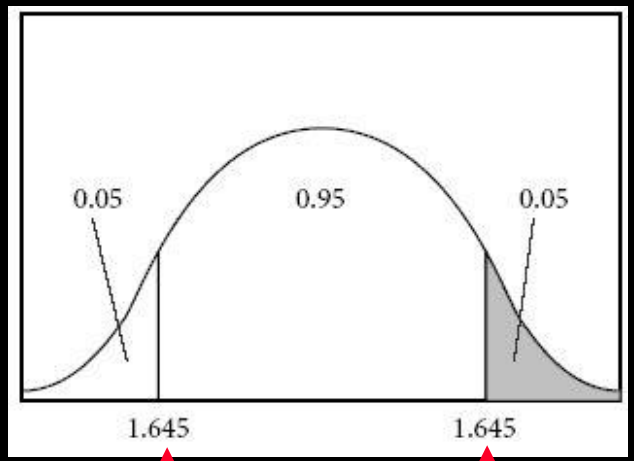

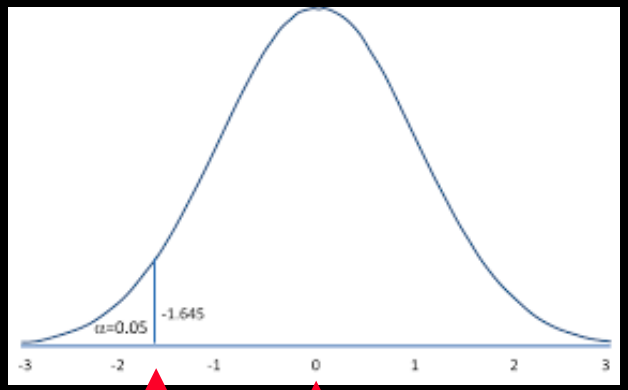

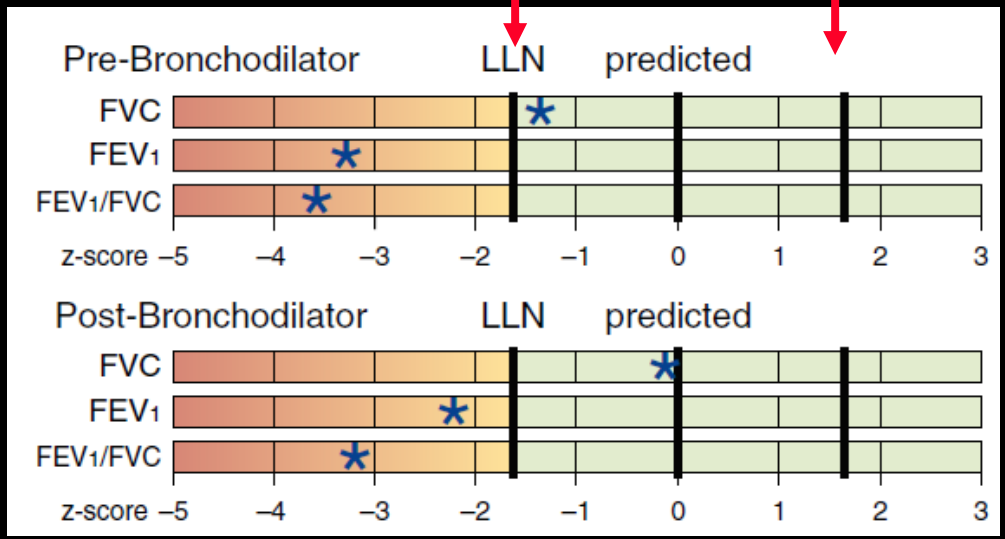

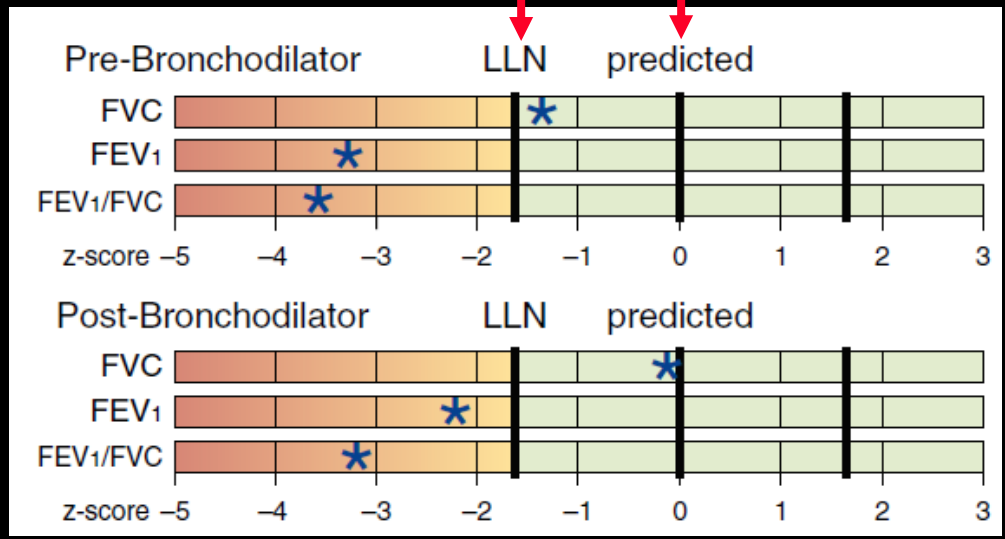

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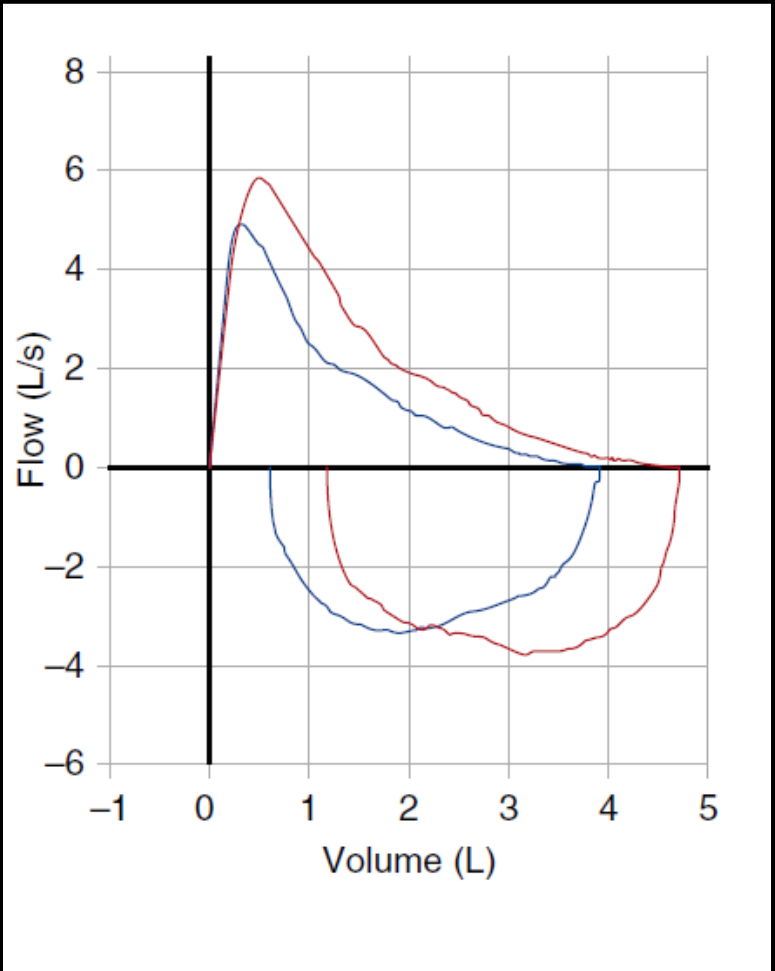

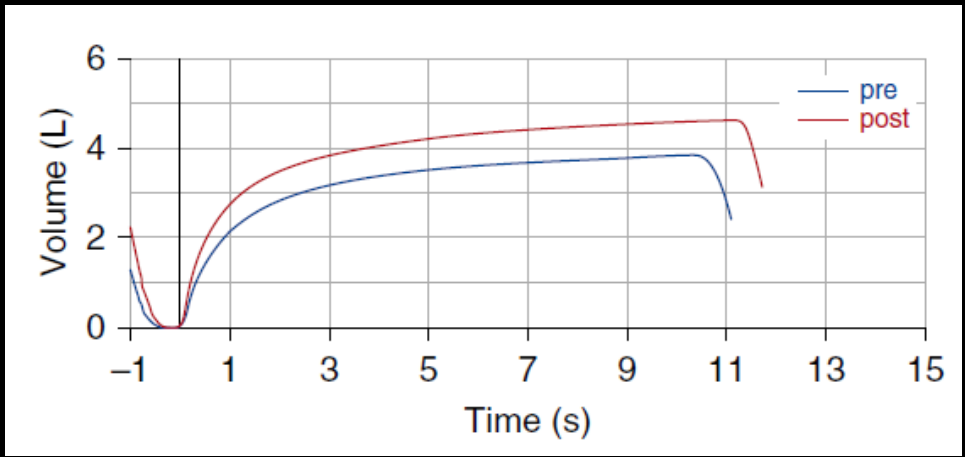

Am J Respir Crit Care Med 2017;196: 1463-1472.

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)

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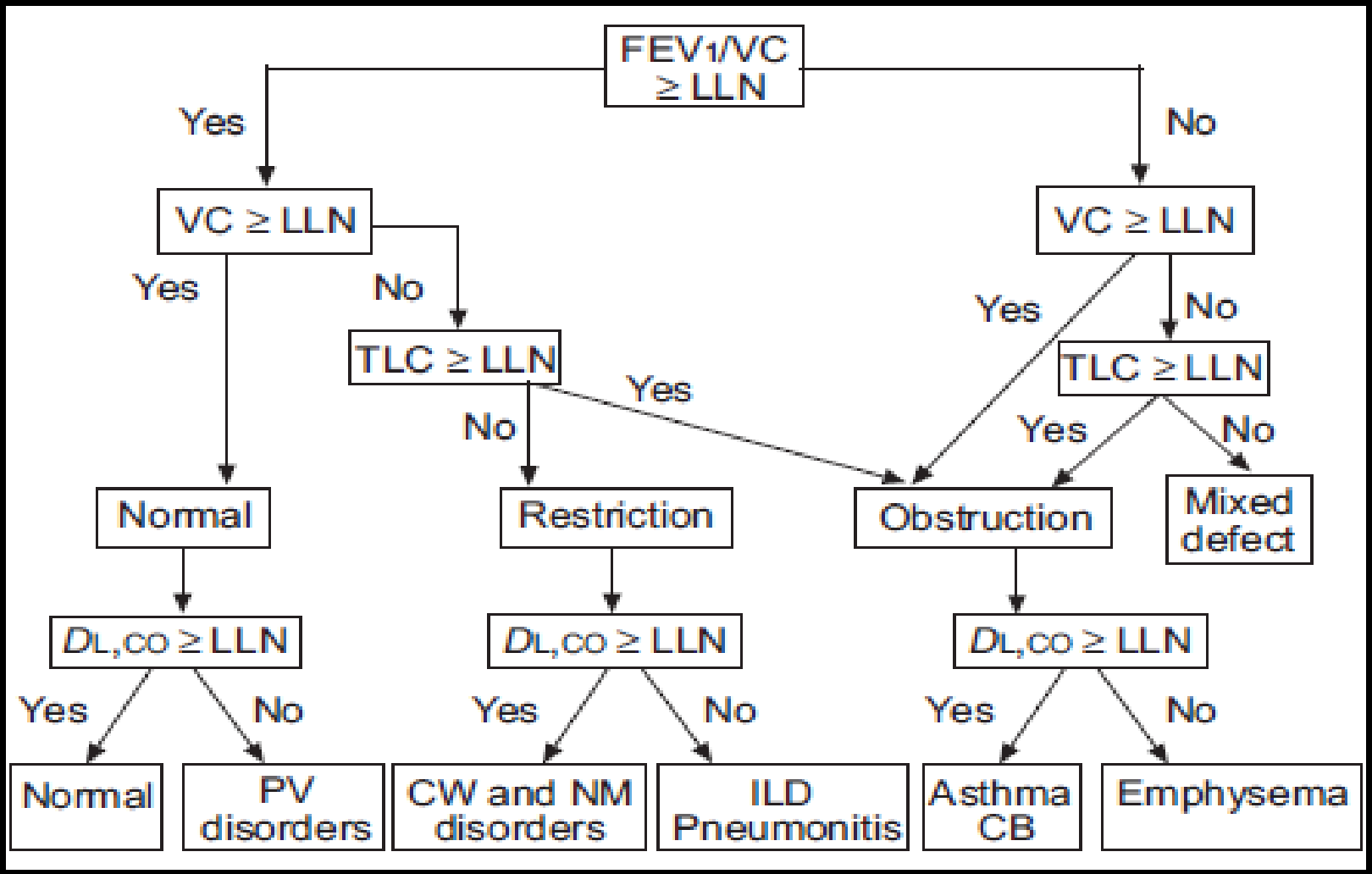
Approach to Evaluation



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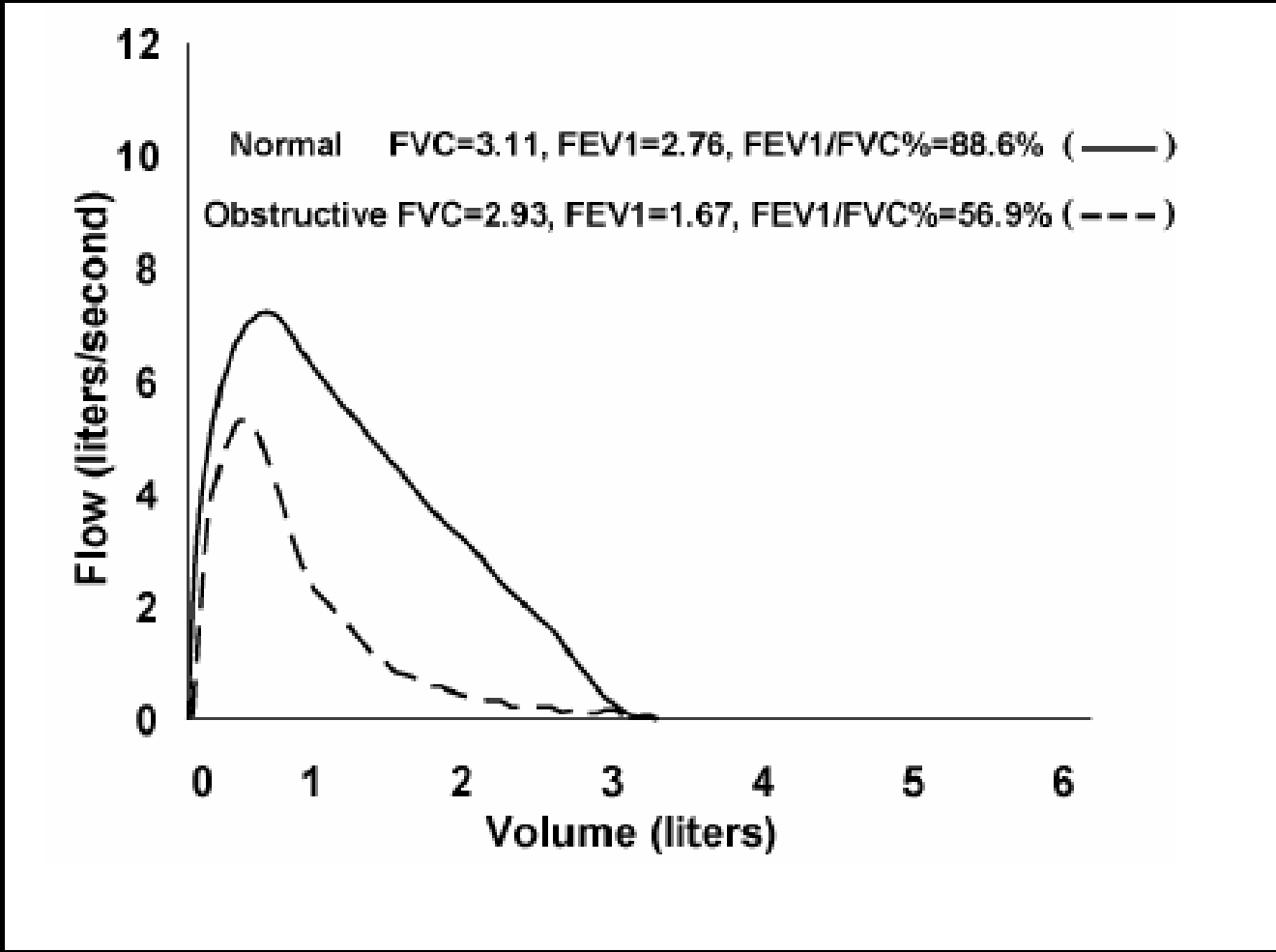
Obstructive Abnormalities

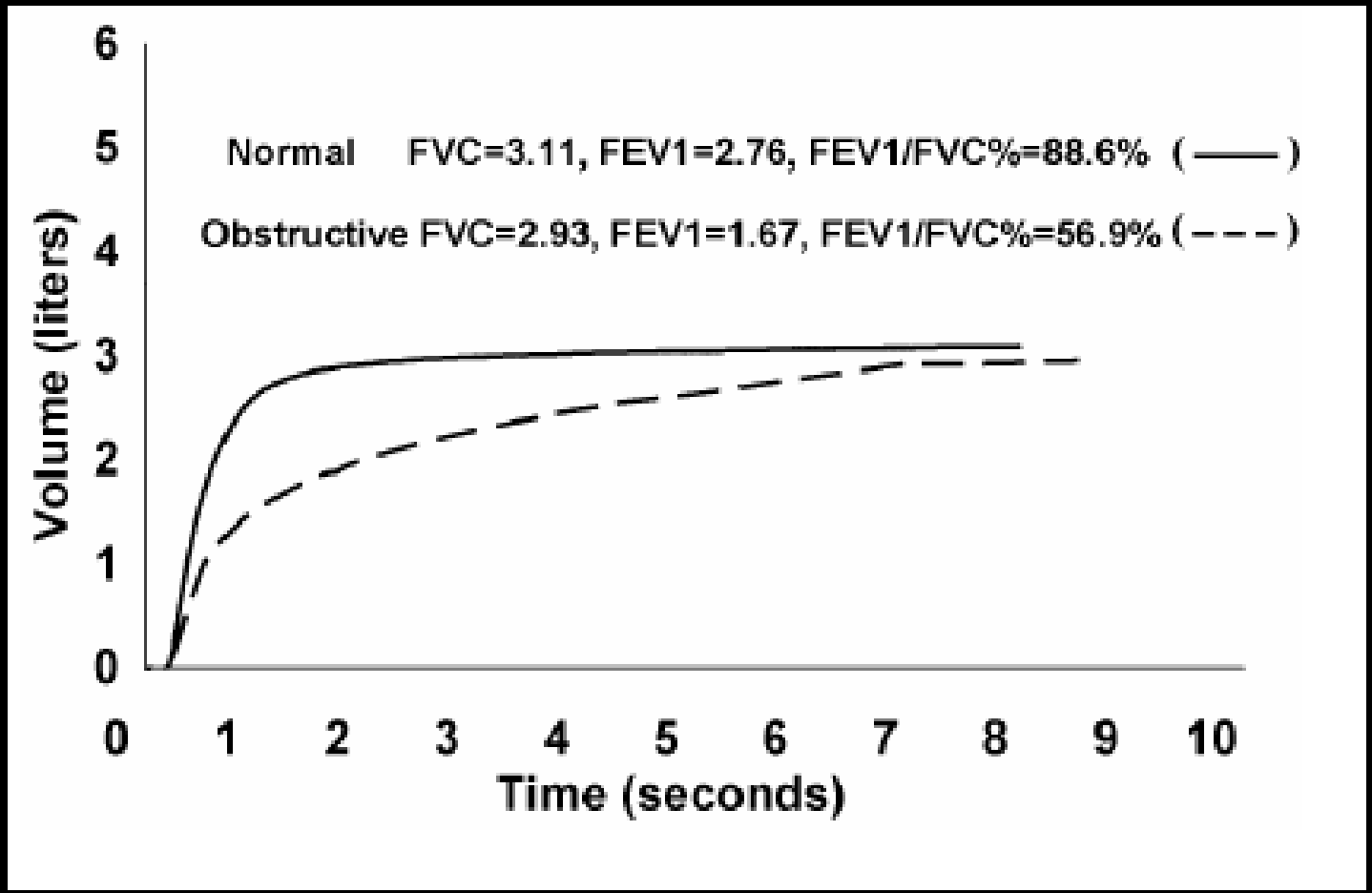
- Disproportionate reduction in maximal airflow (FEV_1) in relation to the maximal volume (VC)
- Implies airway narrowing
- Defined by FEV_1/VC ratio below LLN
- Earliest changes are slowing in terminal portion of spirogram leading to concave shape “scooping”

Obstructive Abnormalities



NIOSH Spirometry Training Guide - cdc.gov/niosh/

Obstructive Abnormalities



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

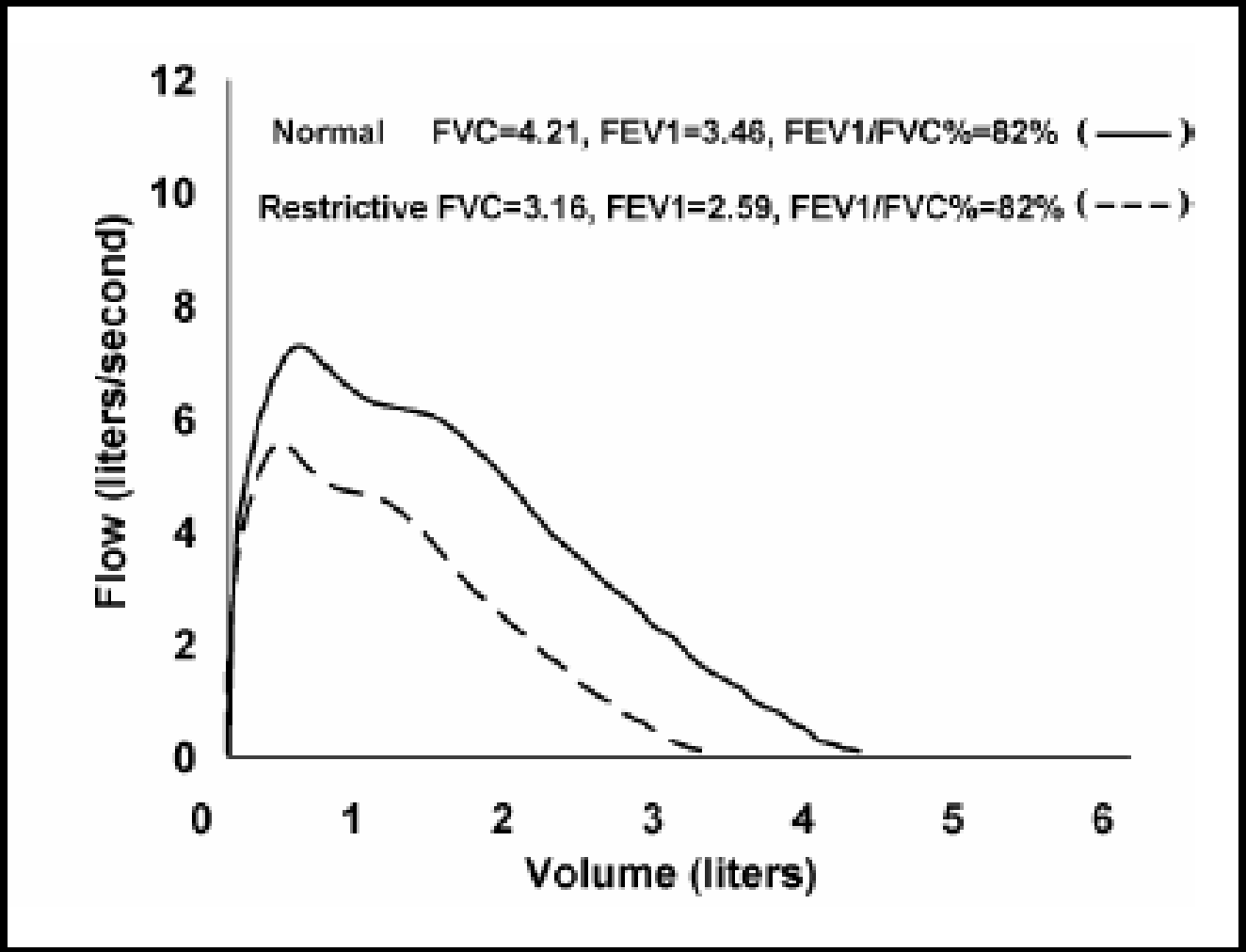
% pred: % predicted.

Eur Respir J 2005;26:948-68.

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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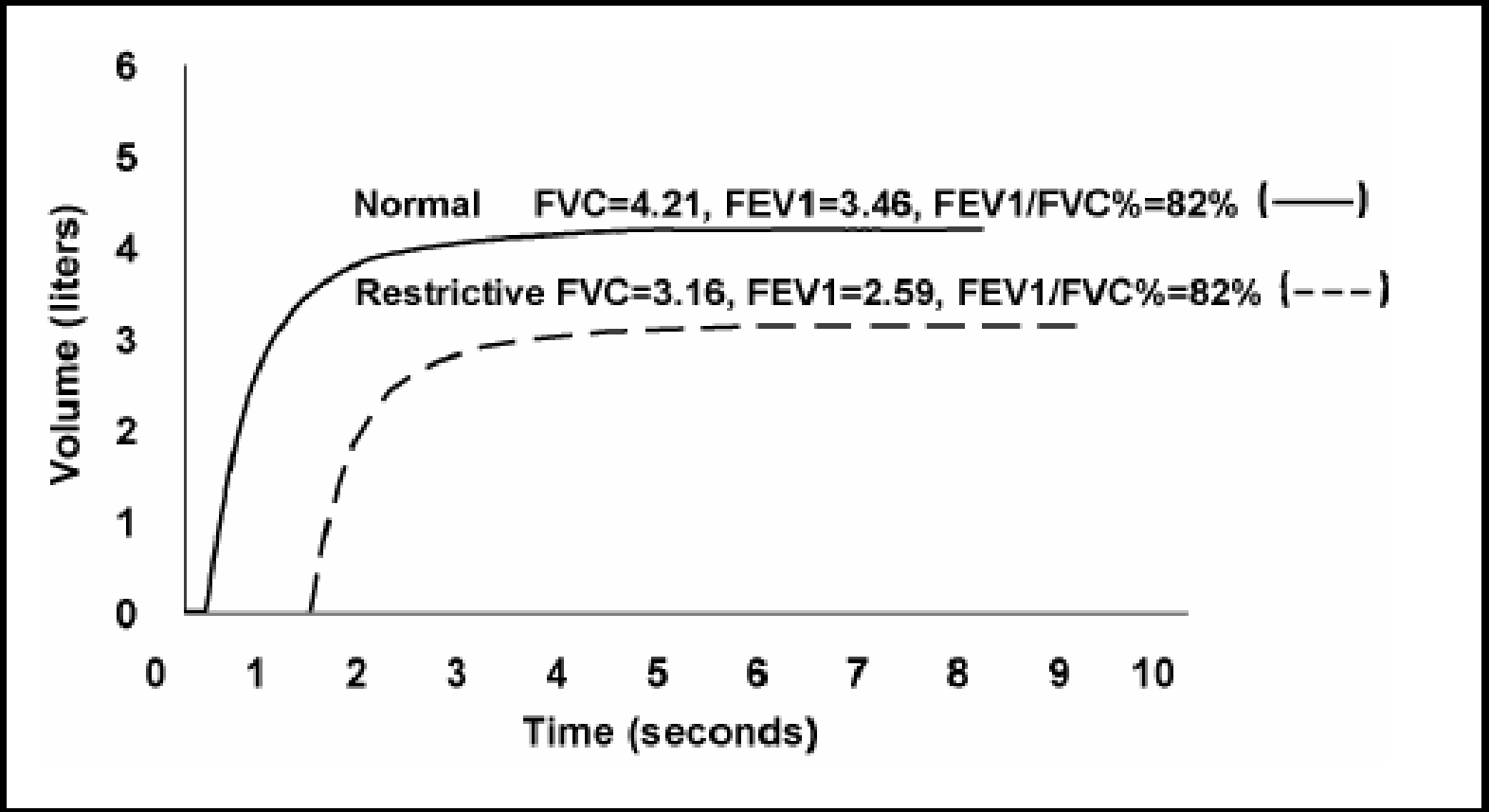
Restrictive Abnormalities



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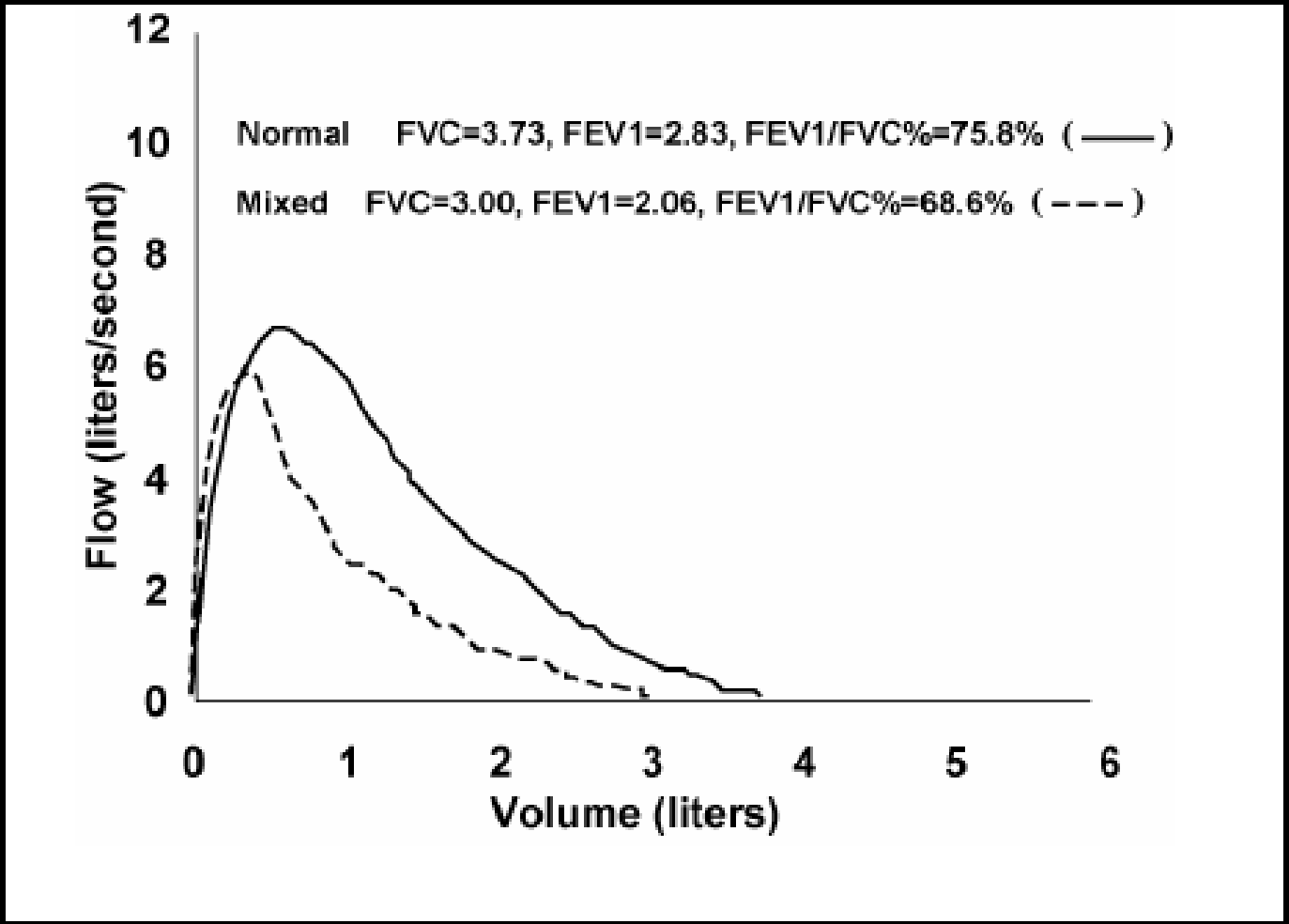
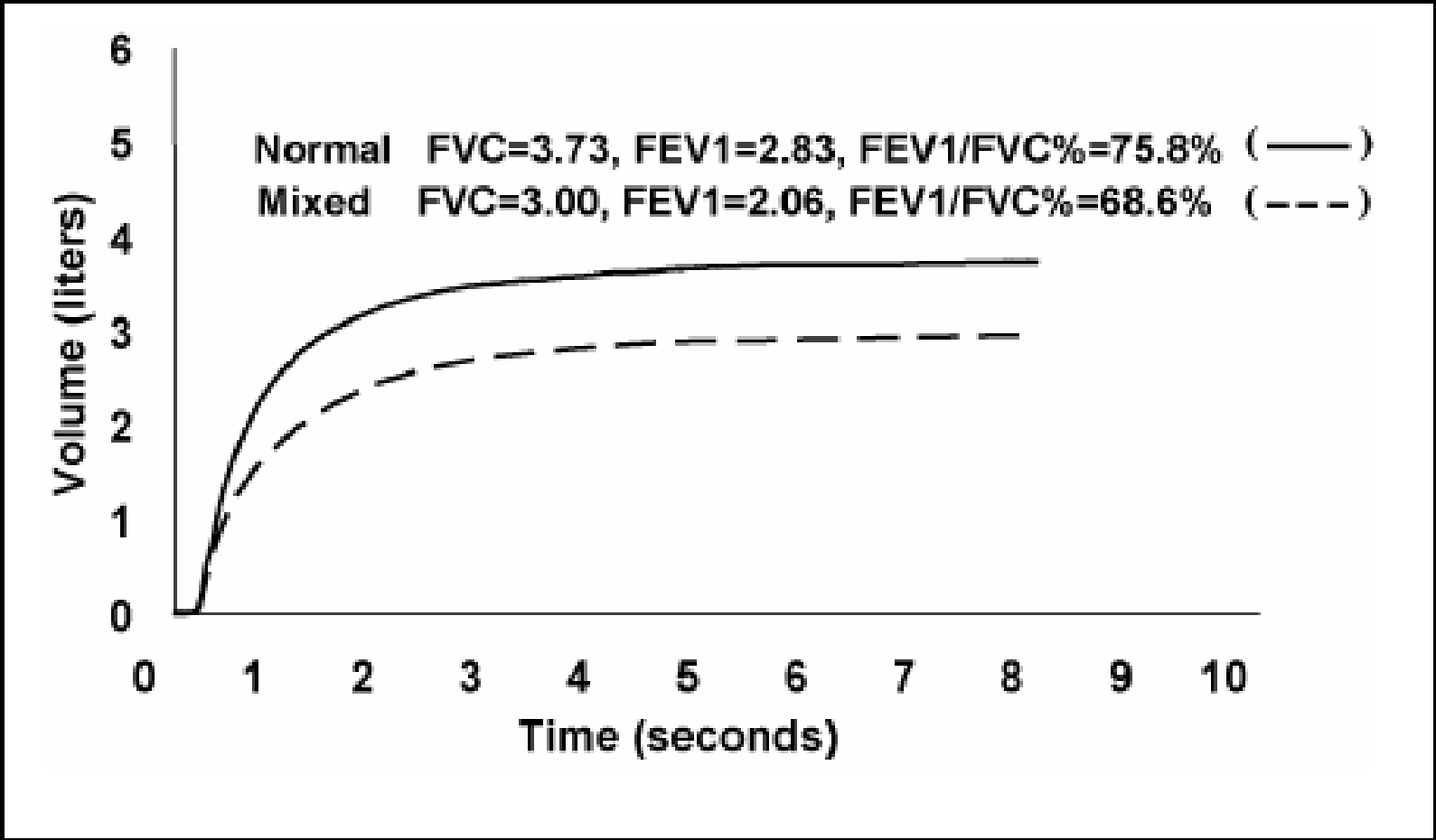
Mixed Abnormalities

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

Mixed Abnormalities



Mixed Abnormalities



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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

Instumentation

- ISO 26782
- ISO 26782;2009 Current update, reviewed 2016 with next in 2021
- International Organization for Standardization. ISO 26782. Anaesthetic and respiratory equipment: spirometers intended for the measurement of time forced expired volumes in humans.
- Geneva, Switzerland: International Organization for Standardization; 2016.

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