Spirometry

Kevin Collins, PhD, RRT, RPFT, AE-C
Associate Professor of Respiratory Care
Texas State University

Disclosures

- Association of Asthma Educators
  - President-Elect
  - Chair of the Education Committee
  - Research Director - Reviewer/Referee for the annual conference abstracts & poster presentations
  - Member of the Annual Conference committee
- Past member of the Board of Directors of the Texas Society for Respiratory Care.
- Guidepoint Global, Inc., New York. Clinical advisor for healthcare subject matter expertise.
- Expert Witness representing plaintiff and defense attorneys in cases of respiratory therapists accused of medical negligence.

Learning Objectives

- Describe the pretest procedures for spirometry testing
- Describe the American Thoracic Society spirometry criteria for acceptability and repeatability
- Describe how to identify abnormal lung function using a Z-Score or FEV_1/FVC%.
- Describe how to perform and interpret the results of a spirometry study

IMPORTANCE OF SPIROMETRY IN ASTHMA DIAGNOSIS

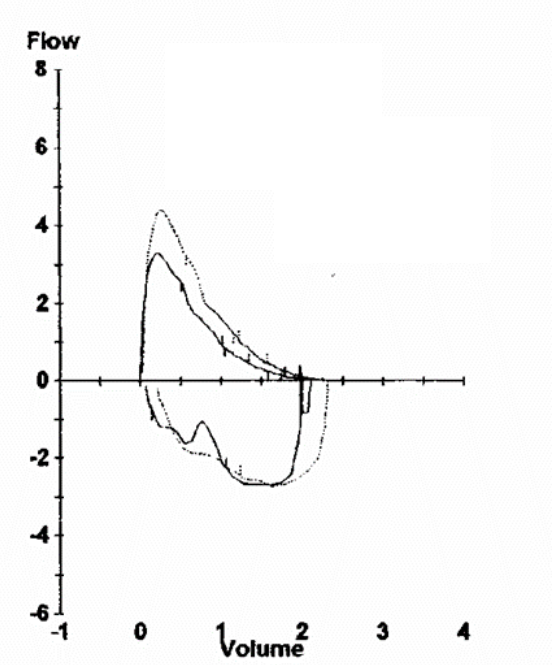
- *Objective assessments of pulmonary function are necessary for the diagnosis of asthma because medical history and physical examination are not reliable means of excluding other diagnoses or of characterizing the status of lung impairment.*

- *NAEPP EPR-3 guidelines recommend spirometry and a before and after bronchodilator study in patients in whom the diagnosis of asthma is being considered.*

Reference: National Asthma Education and Prevention Program, (2007). Third expert panel on the diagnosis and management of asthma. National Heart, Lung, and Blood Institute. Bethesda, MD.

Assessment & Monitoring of Asthma: Spirometry

- The most readily available and useful pulmonary function test which measures flow rates and volumes.
- It is a key diagnostic test for asthma.



McCormack MC, Stoller JD, & Hollingsworth, H. Overview of pulmonary function testing in adults. UpToDate Clinical Resources Database, May 27, 2020. Accessed on February 7, 2020 at www.uptodate.com.

AAE

AMERICAN THORACIC SOCIETY DOCUMENTS

Standardization of Spirometry 2019 Update

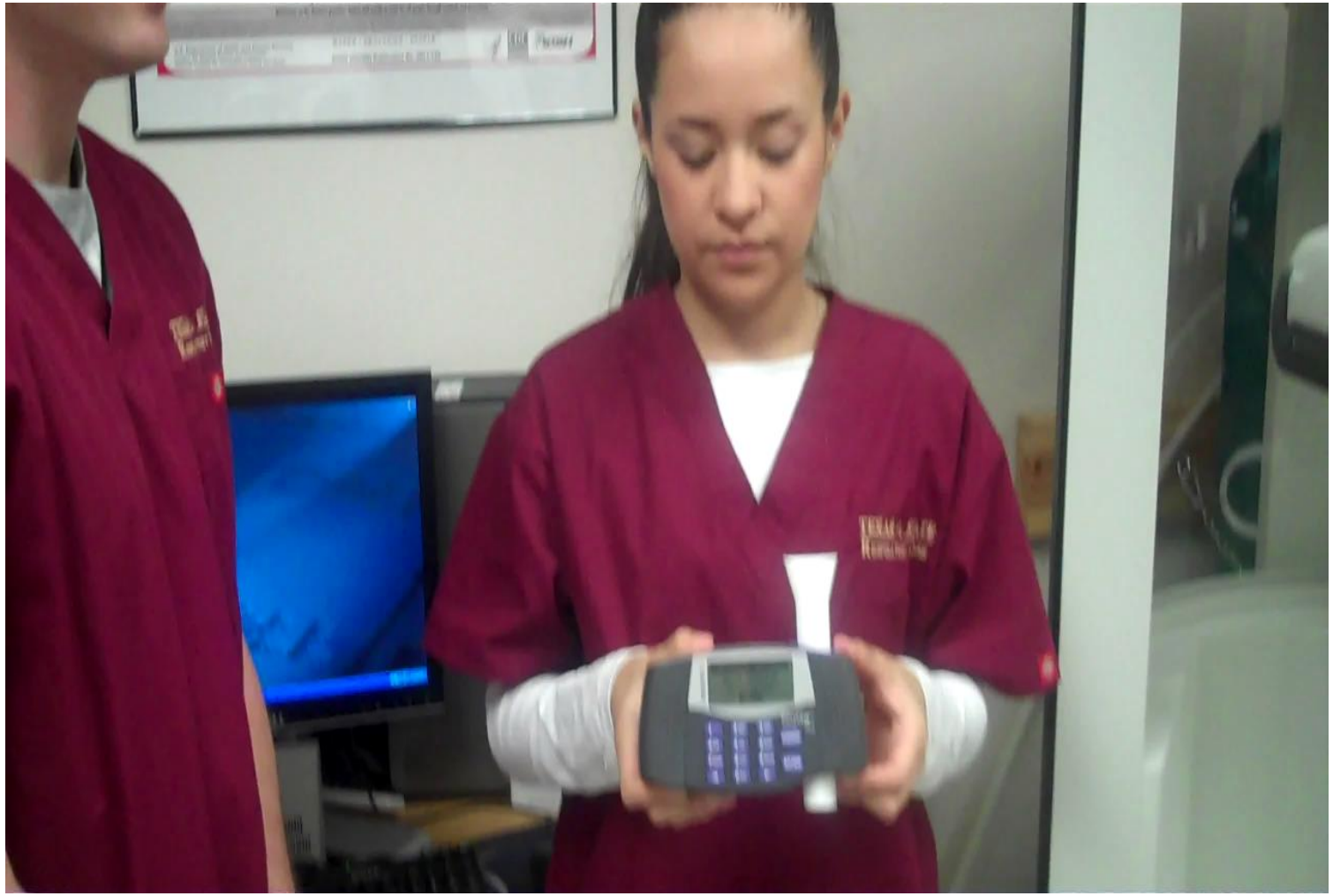
An Official American Thoracic Society and European Respiratory Society Technical Statement

Brian L. Graham, Irene Steenbruggen, Martin R. Miller, Igor Z. Barjaktarevic, Brendan G. Cooper, Graham L. Hall, Teal S. Hallstrand, David A. Kaminsky, Kevin McCarthy, Meredith C. McCormack, Cristine E. Oropez, Margaret Rosenfeld, Sanja Stanojevic, Maureen P. Swanney†, and Bruce R. Thompson; on behalf of the American Thoracic Society and the European Respiratory Society

THIS OFFICIAL TECHNICAL STATEMENT WAS APPROVED BY THE AMERICAN THORACIC SOCIETY AND THE EUROPEAN RESPIRATORY SOCIETY SEPTEMBER 2019

www.thoracic.org

Spirometry Test



Activities That Should Be Avoided before Pulmonary Function Testing

- **Smoking and/or vaping** and/or water pipe use within 1 hour before testing
  (to avoid acute bronchoconstriction due to smoke inhalation)
- **Consuming intoxicants** within 8 hours before testing
  (to avoid problems in coordination, comprehension, and physical ability)
- **Performing vigorous exercise** within 1 hour 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)

Pretest Procedures

Typical 3L Syringe for Calibration

- **Spirometer calibration verification**
  - ATS spirometry guidelines recommend that spirometers have the device calibration verified daily with a 3 Liter calibration syringe.
- **Testing personnel performance**
  - Poorly trained, incompetent testing personnel are the primary cause of low-quality spirometry tests (*accuracy versus precision*).
- **Gathering accurate demographics**
  - Age, Sex, Height, and Race
- **Test quality and common errors**
  - Spirometry testing requires the patient to perform strenuous and precise physical maneuvers to capture accurate data.

What is Normal?

Selecting & Using Reference Values

The physical characteristics that most influence pulmonary function include:

- Age
- Sex
- Height
- Race

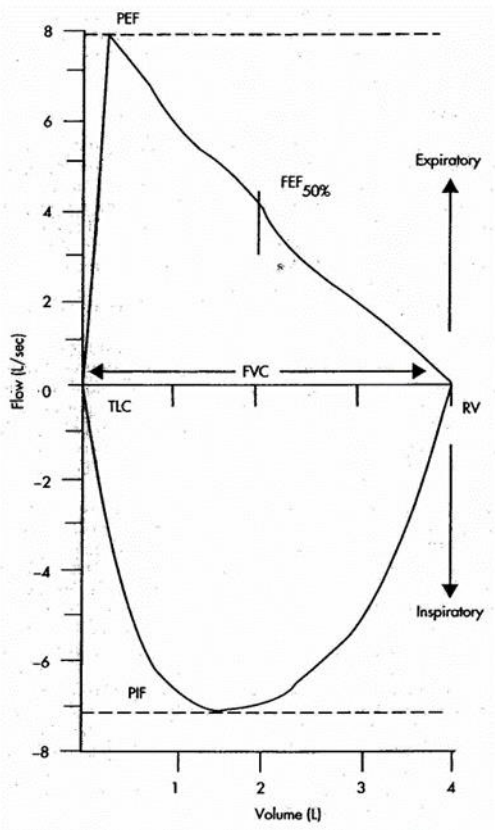
Picture of a typical Stadiometer

In 2017, the ATS recommended that PFT laboratories in North America adopt the *2012 Global Lung Initiative (GLI) reference equations* for spirometry.

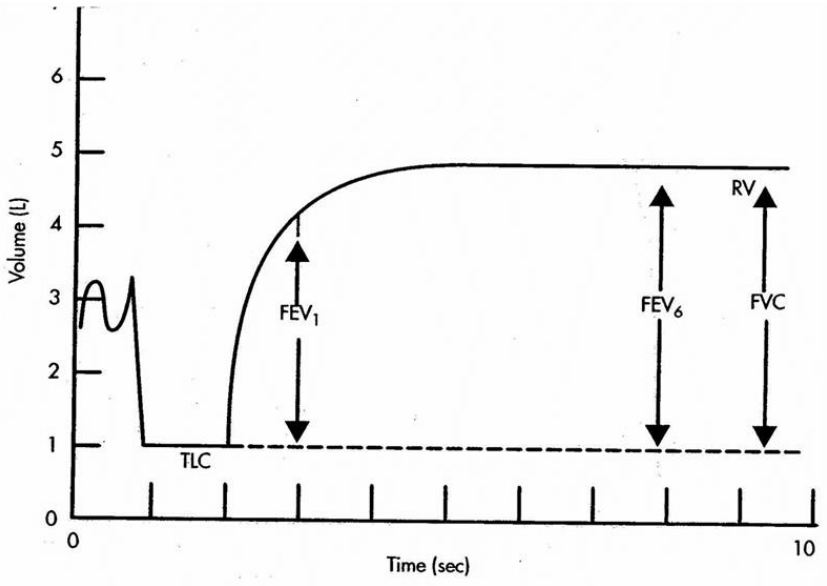
Spirometry: Performing the FVC Maneuver

The 2019 ATS Spirometry update identifies four distinct phases of the FVC maneuver:

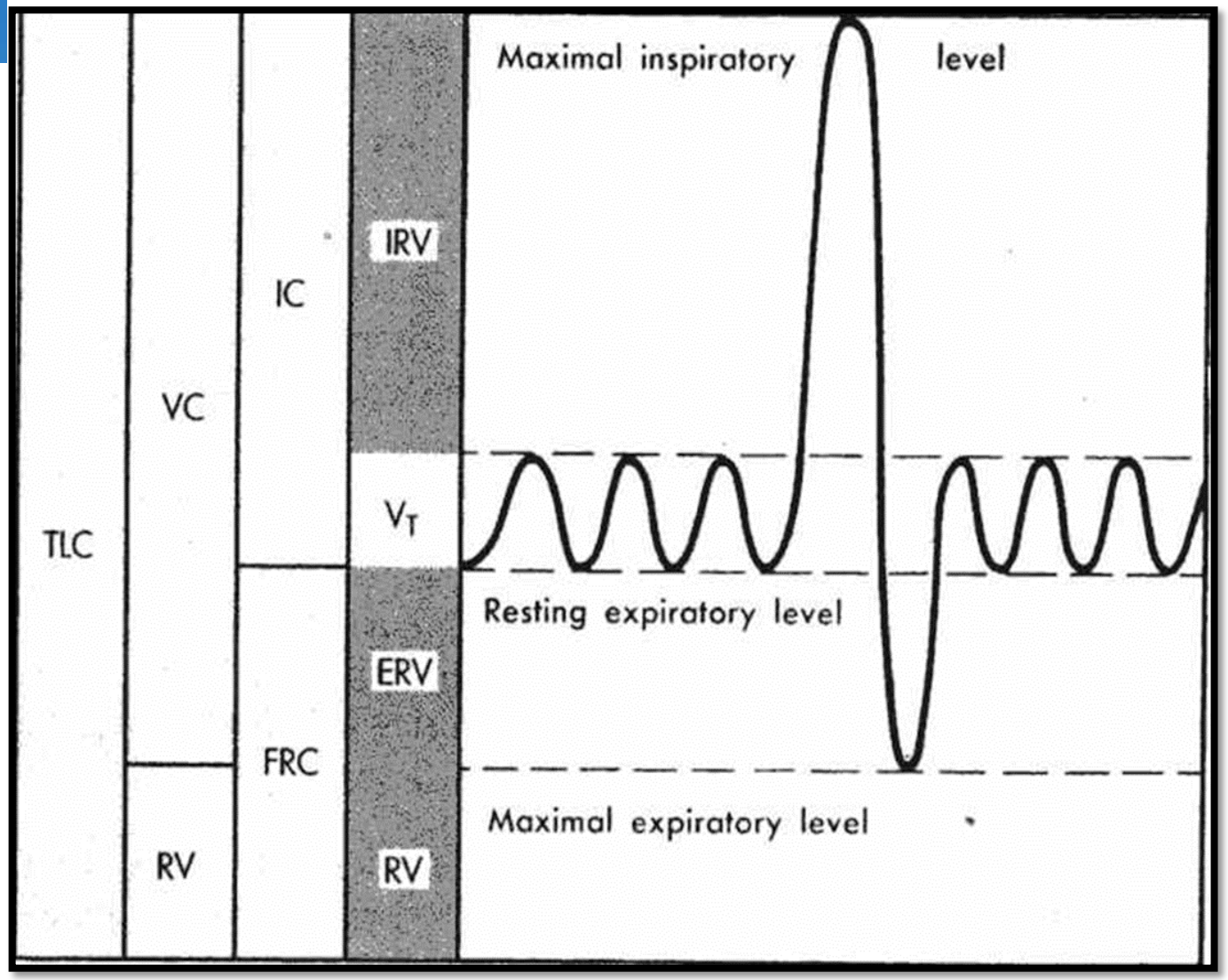
1) Maximal inspiration
2) A “blast” of expiration
3) Continued complete expiration for a maximum of 15 seconds or until a plateau is achieved
4) Inspiration at maximal flow back to maximum lung volume



FLOW-VOLUME LOOP



VOLUME-TIME CURVE



Lung Volumes & Capacities

Spirometry Report

Pre-Test

Parameter	Best	Trial4	Trial1	Trial2	Pred	%Pred
FVC[L]	3.10	3.02	3.10	2.86*	3.63	86
FEV1[L]	2.72	2.72	2.53	2.53	3.02	90
FEV1/FVC[%]	87.6	90.0	81.7	88.7	83.8	105
PEF[L/min]	469.8	469.8	478.4	489.4	-.-	--
FEF25-75[L/s]	3.87	3.87	2.77	3.66	3.31	117
FET[s]	4.22	4.22	5.05	3.29	-.-	--

* Indicates Below LLN or Significant Post Change

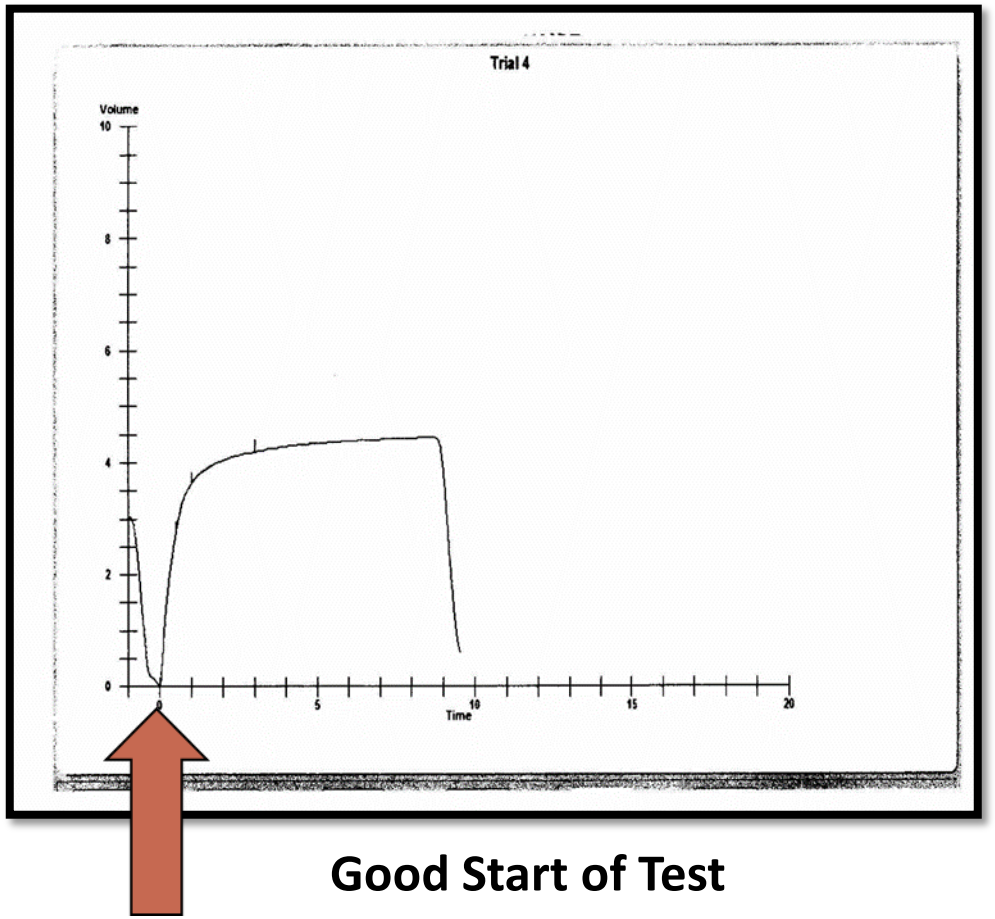
Pre-Test FEV1 Var=0.19L 6.8%; FVC Var=0.03L 2.6%; Session Quality C

Interpretation Normal Spirometry

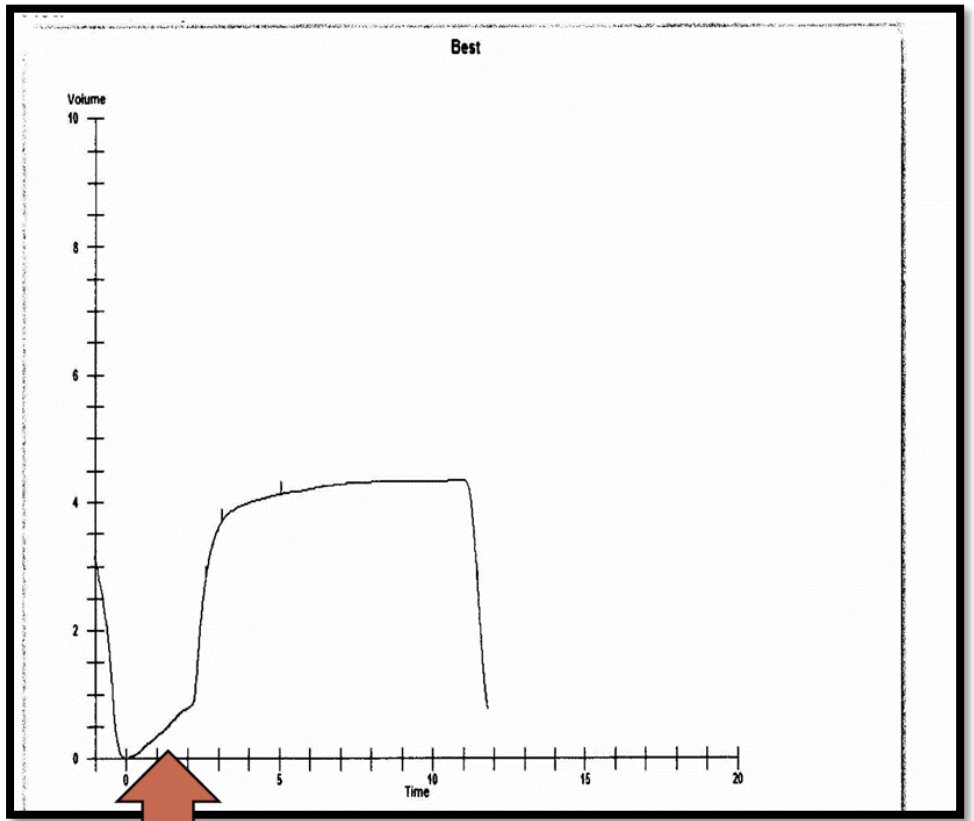
FVC Maneuver 2019 ATS Criteria for Acceptability

- **Maximal effort:** No cough or glottic closure during the first second; no leaks or obstruction of the mouthpiece
- **Good start-of-test**: back extrapolated volume error
- **End of forced expiration (EOFE):**
  - *A plateau is observed*
  - *The patient has achieved an FET of 15 seconds*
  - *The patient repeatedly achieves the same FVC*
- **Three acceptable spirograms** obtained; two largest FVC values within 150 ml; two largest FEV_1 values within 150 ml
- **Report the highest FVC and highest FEV_1**
- **Maximum of 8 attempts**

Back Extrapolated Volume Error



Good Start of Test

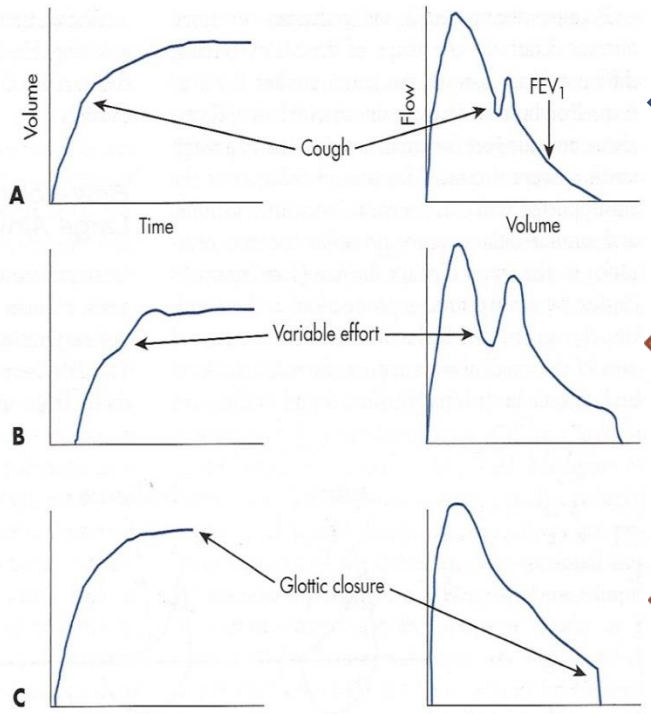


Hesitation at Start of Test

Variability in Spirometry Results

- Inadequate and variable inspiration to TLC
- Ending the expiration prematurely
- Variable effort

Common Errors



Cough

Variable Effort

Glottic Closure

The Ratio (FEV_1 / FVC %)

The ratio of FEV_1 to FVC is expressed as follows:

$$FEV_{1\%} = \frac{FEV_1}{FVC} \times 100$$

$FEV_{1\%}$ is also commonly written as FEV_1/FVC%

* *Normal $FEV_{1\%}$ ratio for a healthy adult is 75%-85%*

Expressed as a percentage as related to normative values as a percentage of predicted.

FEV_1/FVC ratio is utilized to determine if airways obstruction is present.

Spirometry

		Ref	Pre Meas	Pre % Ref
FVC	Liters	5.17	4.11	79
FEV1	Liters	3.95	2.37	60
FEV1/FVC	%	76	58	
FEF25-75%	L/sec	3.33	0.90	27
IsoFEF25-75	L/sec		0.90	
PEF	L/sec	9.87	7.24	73
FET100%	Sec		11.58	

FVC PARAMETERS

Forced Expiratory Volume in One Second (FEV_1)

The severity of airway obstruction is defined by the degree to which the FEV_1 is reduced. The ATS-ERS Task Force suggests the following classifications of severity:

Mild	FEV_1 > 70% predicted
Moderate	FEV_1 = 60%-69% predicted
Moderately severe	FEV_1 = 50%-59% predicted
Severe	FEV_1 = 35%-49% predicted
Very Severe	FEV_1 < 35% predicted

FEV_1 is used to classify the severity of airway obstruction.

Spirometry Report

		Ref	Pre Meas	Pre % Ref
FVC	Liters	3.22	2.12	66
FEV1	Liters	2.53	1.34	53
FEV1/FVC	%	78	63	
FEF25-75%	L/sec	2.46	0.69	28
PEF	L/sec		3.81	

Is airways obstruction present?

If so, what is the severity of airways obstruction?

Yes, moderately severe airways obstruction.

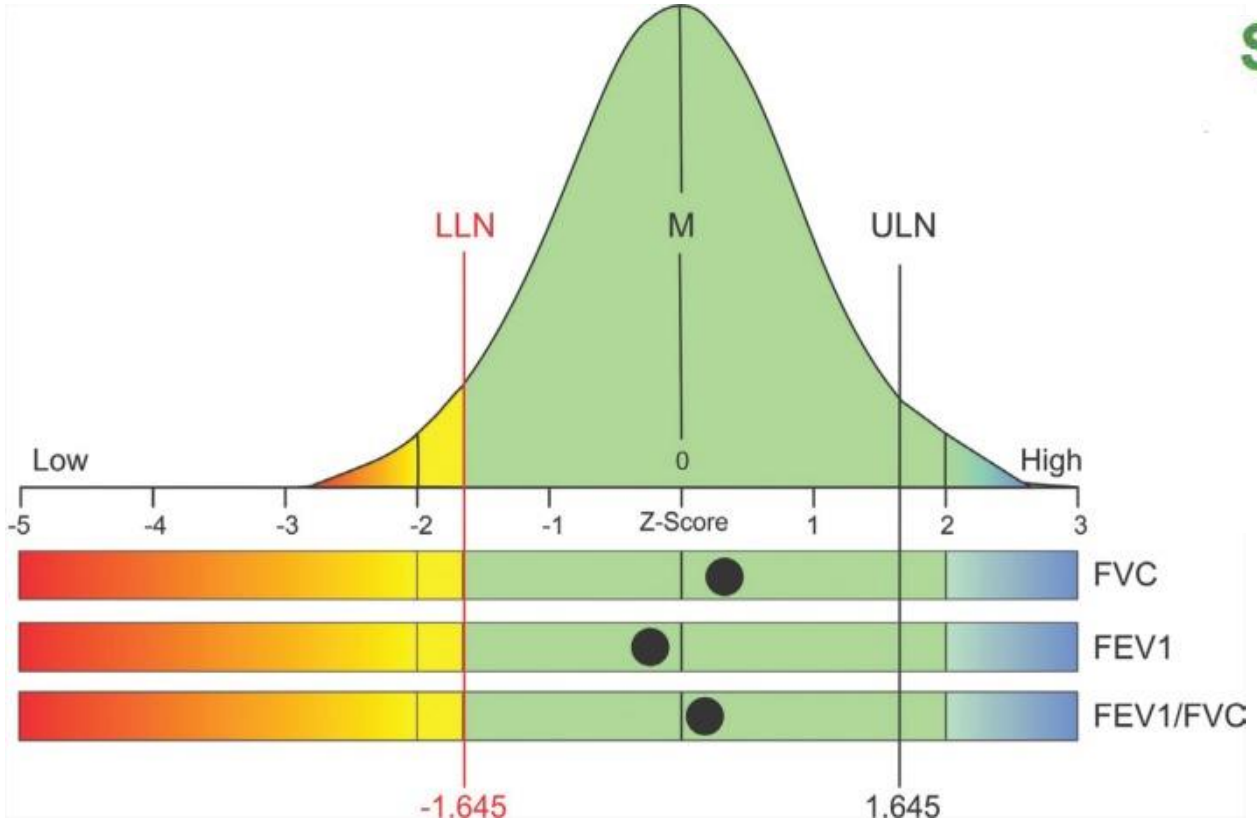
Interpretation of Spirometry Results

- Normal lung function
  - Using a fixed percentage: normal range is 80% - 120% of predicted
  - Z-Score and Lower Limit of Normal (LLN)
  - Z-Score is the number of SDs any value is from the center of the bell curve.
- Airways obstruction
  - FEV_1/FVC % < 70% (rule of thumb)
- Airways restriction
  - Spirometry results may hint at airways restriction, i.e., FVC < 80% of predicted (lung volumes testing needed to confirm)
- Mixed airways obstruction & restriction
  - Reduced FVC (< 80% of predicted) & FEV_1/FVC% < predicted

Interpretative Strategies: What are "normal" values?

The Z-Score & the Lower Limit of Normal (LLN)

The ratio (FEV_1/FVC%) and a fixed Percent (%) Predicted (80%-120%)



Spirometry

		Ref	Pre Meas	Pre % Ref
FVC	Liters	3.12	2.19	70
FEV1	Liters	2.43	1.52	63
FEV1/FVC	%	79	69	
FEF25-75%	L/sec	2.35	0.97	41
IsoFEF25-75	L/sec		0.97	
PEF	L/sec	6.12	3.77	62
FET100%	Sec		8.56	

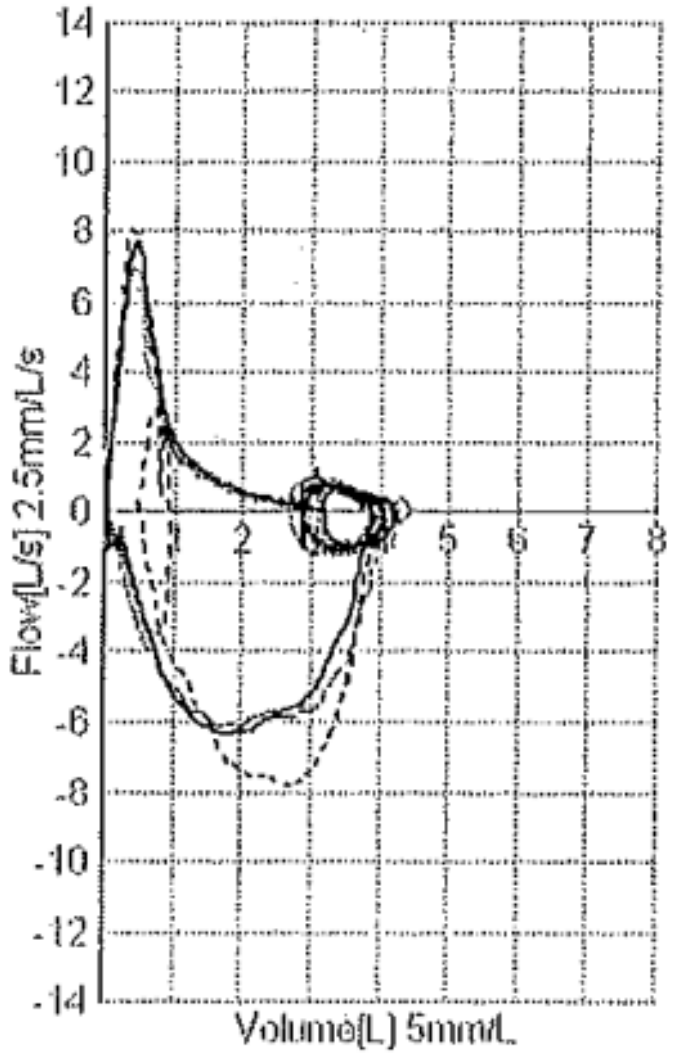
Spirometry Report

Pre-Test

Parameter	Best	Trial4	Trial1	Trial2	Pred	%Pred
FVC[L]	3.19*	3.19*	3.10*	3.15*	4.34	73
FEV1[L]	1.84*	1.84*	1.80*	1.72*	3.27	56
FEV1/FVC[%]	57.6*	57.6*	58.0*	54.6*	75.6	76
PEF[L/min]	461.6	461.6	481.6	421.2	---	--
FEF25-75[L/s]	0.79*	0.79*	0.82*	0.67*	2.45	32
FET[s]	6.48	6.48	5.80	7.58	---	--
FIVC[L]	3.97	3.84	3.43	3.97	4.34	92
PIF[L/min]	382.1	382.1	471.2	370.1	---	--

* Indicates Below LLN or Significant Post Change

Pre-Test FEV1 Var=0.04L 2.2% FVC Var=0.04L 1.3% Session Quality A

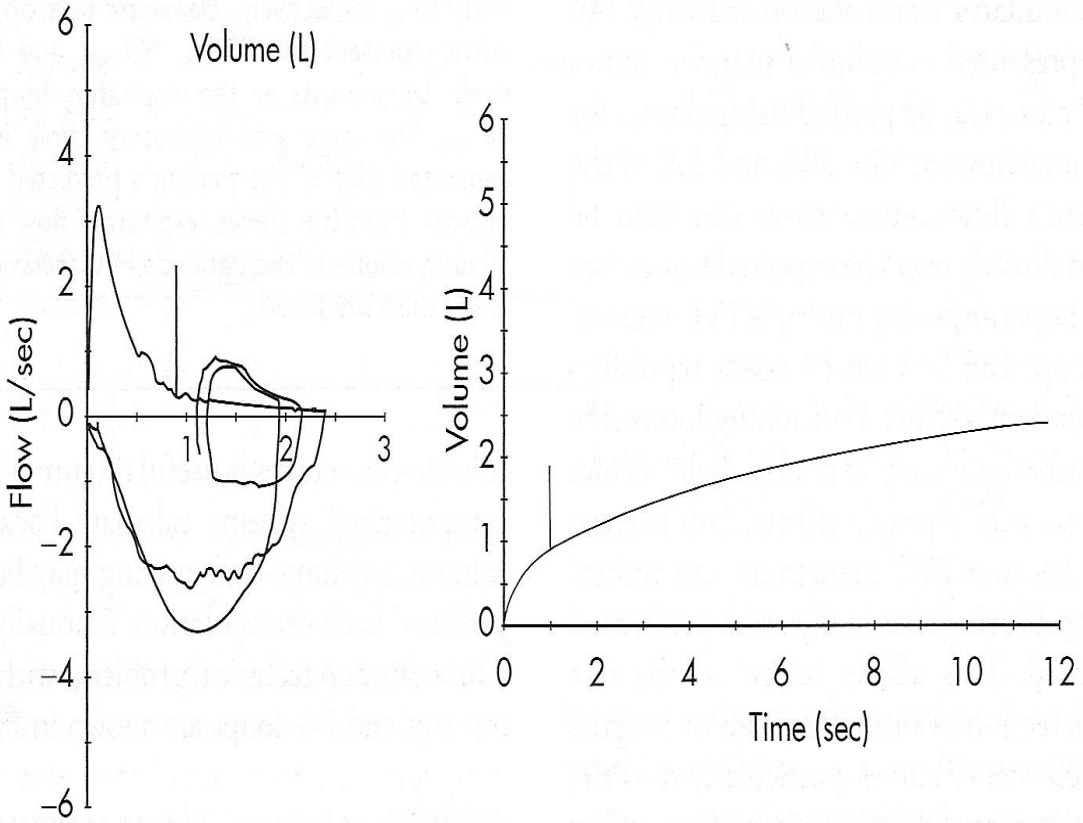


What is the interpretation of this spirometry report?

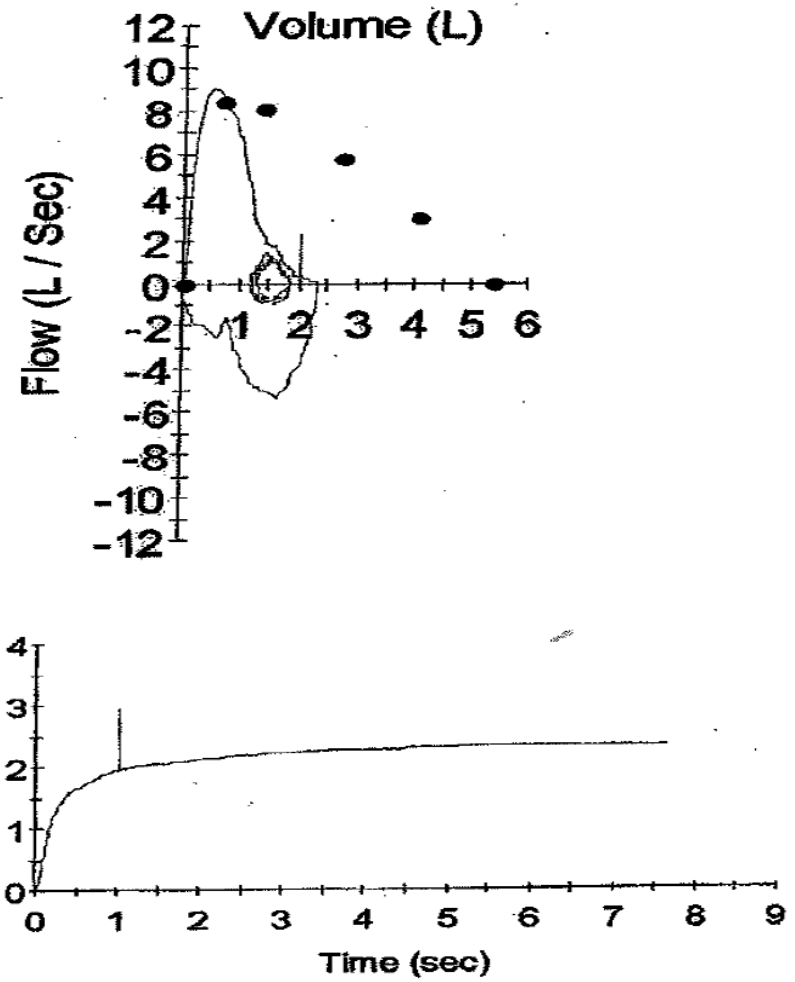
Moderately severe airways obstruction.

Flow-Volume Loop

Flow Volume Loop and Volume Time Curve (Airways Obstruction)



Flow Volume Loop and Volume Time Curve (Airways Restriction)



Spirometry

		Ref	Pre Meas	Pre % Ref
FVC	Liters	5.17	4.11	79
FEV1	Liters	3.95	2.37	60
FEV1/FVC	%	76	58	
FEF25-75%	L/sec	3.33	0.90	27
IsoFEF25-75	L/sec		0.90	
PEF	L/sec	9.87	7.24	73
FET100%	Sec		11.58	

What is the interpretation?

Moderate airways obstruction.

Spirometry Report

Parameter	Pre-Test Best	Pred	%Pred
FVC[L]	3.10	3.63	86
FEV1[L]	2.72	3.02	90
FEV1/FVC[%]	87.6	83.8	
PEF[L/min]	469.8	-.-	--
FEF25-75[L/s]	3.87	3.31	117

What is the interpretation of this spirometry test?

- Airways obstruction
- Suggestive of airways restriction
- Normal spirometry

FVC Interpretive Strategies

- Are FVC and FEV_1 repeatable (within 150 ml)?
- Are reference values appropriate? Age? Sex? Height? Race?
- Is FEV_1/FVC% less than predicted? If so, obstruction is present.
- Are both FVC and FEV_1 reduced proportionately? If so, restriction may be present? Lung volumes are indicated.
- Are the spirometric findings consistent with the patient history and physical findings?

Before and After Bronchodilator Studies

- Spirometry performed before and after bronchodilator administration to determine the degree of improvement of airflow in response to a bronchodilator.
- FEV_1/FVC% less than predicted is a good indication for bronchodilator studies.
- Withhold bronchodilator therapy before testing.
- Administer bronchodilator with MDI/holding chamber or Nebulizer.

		Ref	Pre Meas	Pre % Ref
FVC	Liters	3.22	2.12	66
FEV1	Liters	2.53	1.34	53
FEV1/FVC	%	78	63	
FEF25-75%	L/sec	2.46	0.69	28
PEF	L/sec		3.81	

2019 ATS Update: Bronchodilator withholding times

Bronchodilator Medication	Withholding Time
SABA (e.g., albuterol or salbutamol)	4–6 h
SAMA (e.g., ipratropium bromide)	12 h
LABA (e.g., formoterol or salmeterol)	24 h
Ultra-LABA (e.g., indacaterol, vilanterol, or olodaterol)	36 h
LAMA (e.g., tiotropium, umeclidinium, aclidinium, or glycopyrronium)	36–48 h

Before- and after-Bronchodilator Studies

- FEV_1 is the most used test for quantifying bronchodilator response
- Re-assess lung function after 15 minutes
- Reversibility of airway obstruction is considered significant for increases greater than 12% *and* 200 ml for either FEV_1 or FVC.
- The lack of a response to bronchodilator testing does not preclude a clinical response to bronchodilator therapy
- FEV_1/FVC % should not be used to judge bronchodilator response

Before- and after- Bronchodilator Studies

Spirometry Report

	(BTPS)	PRED	PRE-RX BEST	PRE-RX %PRED	POST-RX BEST	POST-RX %PRED	% CHG
FVC	Liters	4.28	2.43	57	2.52	59	4
FEV1	Liters	2.93	1.83	62	1.97	67	8
FEV1/FVC	%	69	75		78		
FEF25-75%	L/sec	2.74	1.39	51	1.86	68	33
PEF	L/sec	8.11	7.16	88	6.36	78	-11
FIVC	Liters	4.28	2.29	53	2.23	52	-3
FET100%	Sec		8.05		9.32		16

Reversibility of airway obstruction is considered significant for increases greater than 12% and 200 ml for either FEV_1 or FVC.

Before- and After- Bronchodilator Study

Spirometry Report

		Ref	Pre Meas	Pre % Ref	Post Meas	Post % Ref	Post % Chg
FVC	Liters	3.22	2.12	66	2.33	72	10
FEV1	Liters	2.53	1.34	53	1.57	62	17
FEV1/FVC	%	78	63		68		
FEF25-75%	L/sec	2.46	0.69	28	0.88	36	28
PEF	L/sec		3.81		4.65		22

Reversibility of airway obstruction is considered significant for increases greater than 12% and 200 ml for either FEV_1 or FVC.

Before and after Bronchodilator Study

Spirometry Report

	Pre-Bronch			Post-Bronch		
	Actual	Pred.	%Pred.	Actual	%Pred.	%Chng.
SPIROMETRY						
FVC (L)	2.98	4.62	64	3.31	72	11
FEV1 (L)	0.73	3.31	22	1.04	31	42
FEV1/FVC (%)	24	76	32	31	41	28

Reversibility of airway obstruction is considered significant for increases greater than 12% and 200 ml for either FEV_1 or FVC.

Spirometry Testing Pearls

There are 3 key elements to obtain high quality pulmonary function data:

- Accurate and precise instrumentation,
- A patient capable of performing acceptable and repeatable measurements,
- A motivated technologist to elicit maximum performance from the patient.

Thank You!