Coaching Spirometry

Using **4 maximums** to coach spirometry to meet ATS/ERS criteria for acceptability, usability, and repeatability

AARC Approved for 1 CRCE

Speaker

Vicki Rosette MS RRT RRT-ACCS RPFT

2024 AARC Specialty Practitioner of the Year – Pulmonary Diagnostics

Disclaimer / Conflict of Interest

- None

Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

1. describe the basics of **spirometry context**

2. explain **4 Maximums** within the forced vital capacity maneuver

3. explain **troubleshooting and coaching** to correct spirometry errors and meet ATS/ERS criteria

This presentation does NOT include:

We are only focused on "How to Coach" to meet ATS/ERS criteria

- Theory / Math
- Ordering PFT's
  - Indications,
  - Contraindications,
  - Withholdings
  - Pt Preparation
- Laboratory Management
  - Equipment
  - Calibration
  - Quality systems
  - Reference / Normals
- Interpretation
  - Reporting
    - % predicted
    - LLN / ULN
    - Z-values
  - Pattern / Severity
    - Obstructive / Restrictive
    - Mild / Moderate / Severe
- Clinical significance
  - Diagnostic
  - Therapeutic

Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

1. describe the basics of **spirometry context**

    definitions,

    4 volumes, 4 capacities, 4 levels,

    & operator factors

Definitions

- **Spirometry** is a physiological test that measures the maximal volume of air that an individual can inspire/inhale and expire/exhale with maximal effort. This can be accomplished fast, or forced, as an FVC, or slow, as an SVC.

The most relevant of many measurements:

- **FEV_1:** the **F**orced **E**xpiratory **V**olume is the volume exhaled in the first second of a FVC maneuver

How **Fast** can you breathe?

- **FVC:** the **F**orced **V**ital **C**apacity is the maximum volume delivered during an expiration made as forcefully and completely as possible starting from full inspiration

How **Much** can you breathe?

History of Spirometry Standardization

European Respiratory Society (ERS)
https://www.ersnet.org/

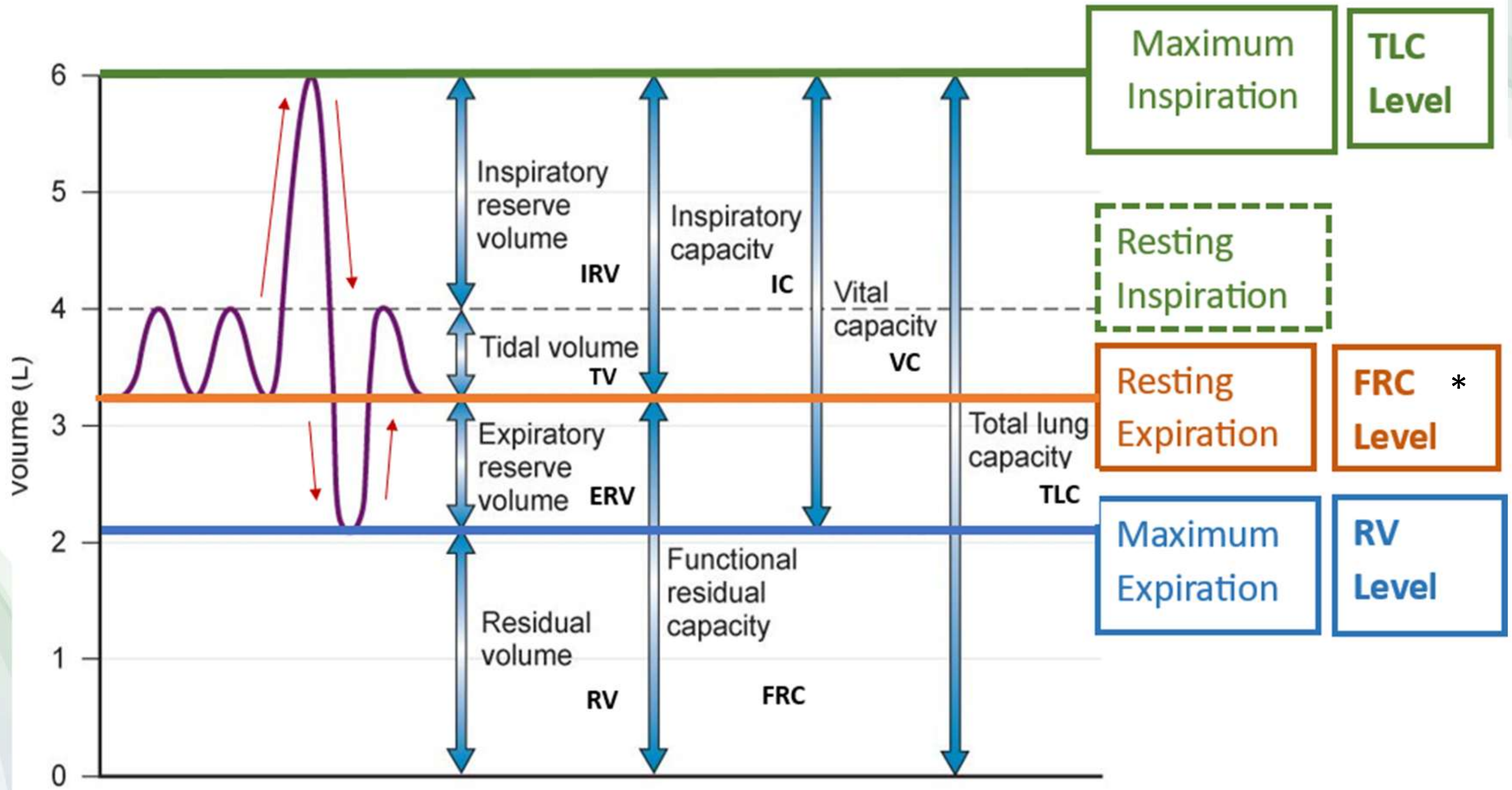
American Thoracic Society (ATS)
https://site.thoracic.org/

- 2019 ATS & ERS Update and Technical Statement
- 2005 **Standardisation** of spirometry *ATS & ERS making the user responsible for ensuring that the equipment measurements remain accurate.*
- 1994 *The* **State-of-the-Art** *for spirometry has continued to advance as a result of scientific studies that have provided additional data related to performance of spirometry*
- 1987 **Gold Standard** - *against which equipment performance and test performance can be optimized.*
- 1979 **Snowbird** – *1st standards proposed for clinical & epidemiologic spirometry studies*

More Definitions

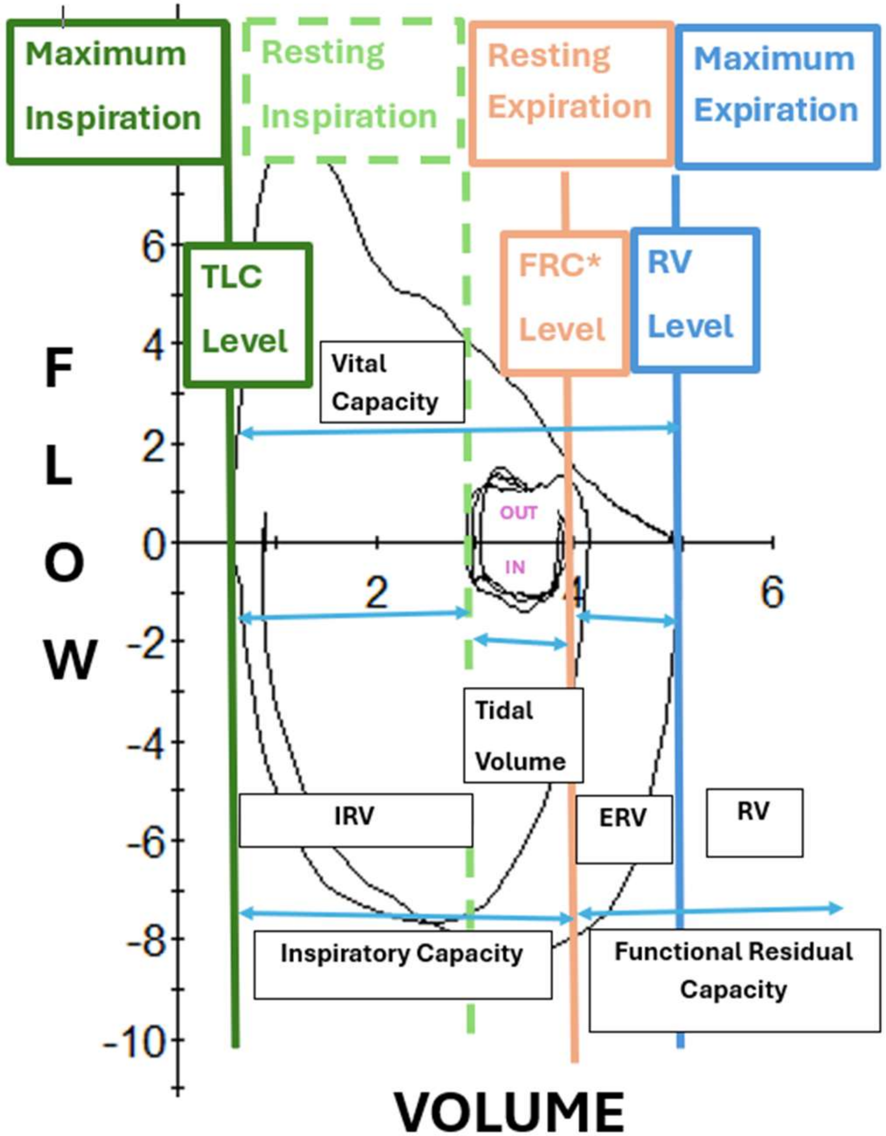
- “Operator” is the person conducting the test
- “Patient” is the person being tested
- “Maneuver” is the term used for the inspiratory and expiratory VC excursions.
- “Must” is used to indicate a requirement
- “Should” is used to indicate best practice

Spirogram: 4 Volumes, 4 Capacities, 4 Levels



** FRC Level is the most reproducible point*

Spirogram:
4 Volumes,
4 Capacities,
4 Levels



** FRC Level is the most reproducible point*

Operator

Three key elements:

- Instrumentation
- Patient
- Operator

Requires:
training
experience

Multiple studies have shown that the overwhelming majority, 90%, of patients can perform PFTs correctly when properly coached.

It is the responsibility of the operator to observe and engage with the patient to achieve optimal results

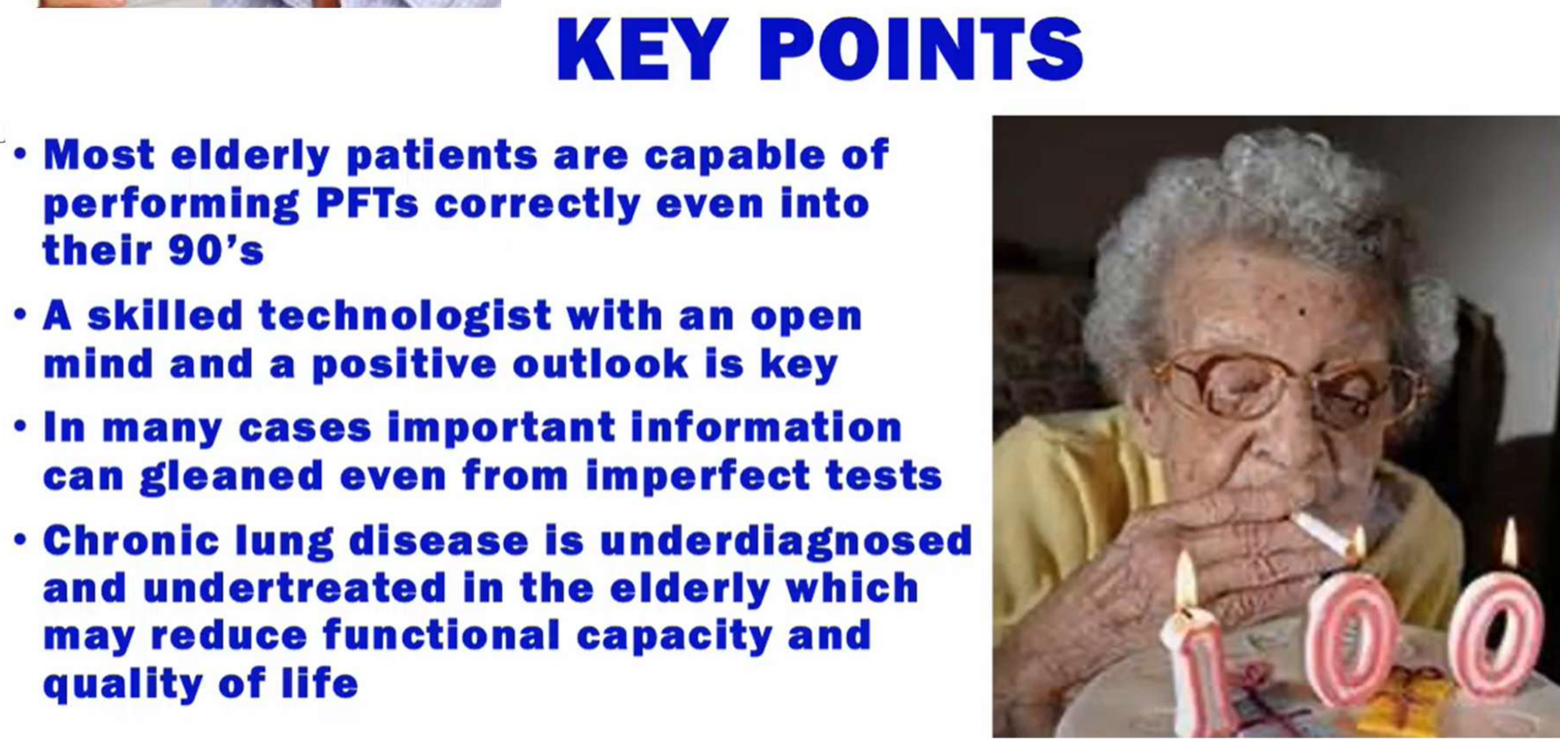
In fact, the most common cause of low quality PFTs is a poorly trained and/or unmotivated technologist.

https://www.morgansci.com/pft-quality/

Implicit Bias

IN HEALTHCARE, IMPLICIT BIAS REFERS TO THE UNCONSCIOUS ATTITUDES AND STEREOTYPES THAT AFFECT HEALTH CARE PROFESSIONALS' UNDERSTANDINGS, ACTIONS, AND DECISIONS REGARDING PATIENT CARE

[PFT Tutor with Jeffrey Haynes: Can Elerly Patients Perform PFTs Correctly?](#) (8:24)



Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

2. explain **4 Maximums** within the forced vital capacity maneuver
    - as part of the spirometry **procedure**
    - as within-maneuver criteria for "**acceptability**" and "**usability**"
    - as between-maneuver criteria for "**repeatability**"
    - as session quality **grading**

Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

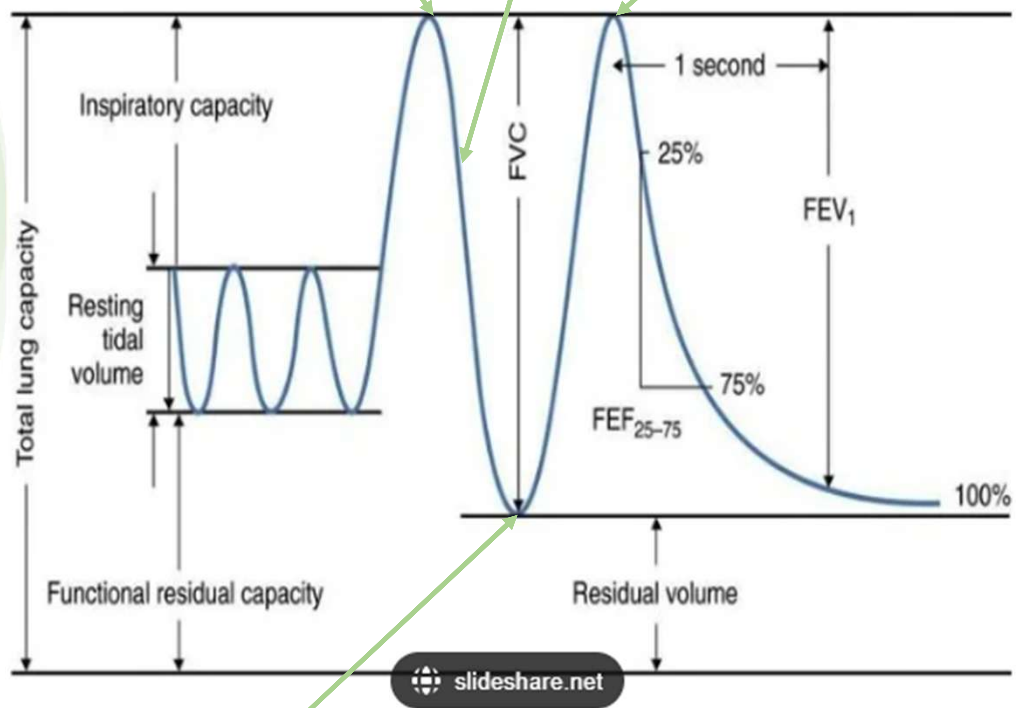
2. explain **4 Maximums** within the forced vital capacity maneuver

Four Maximums Within Maneuver

Maximum (#2) Blast of expiration – FEV1

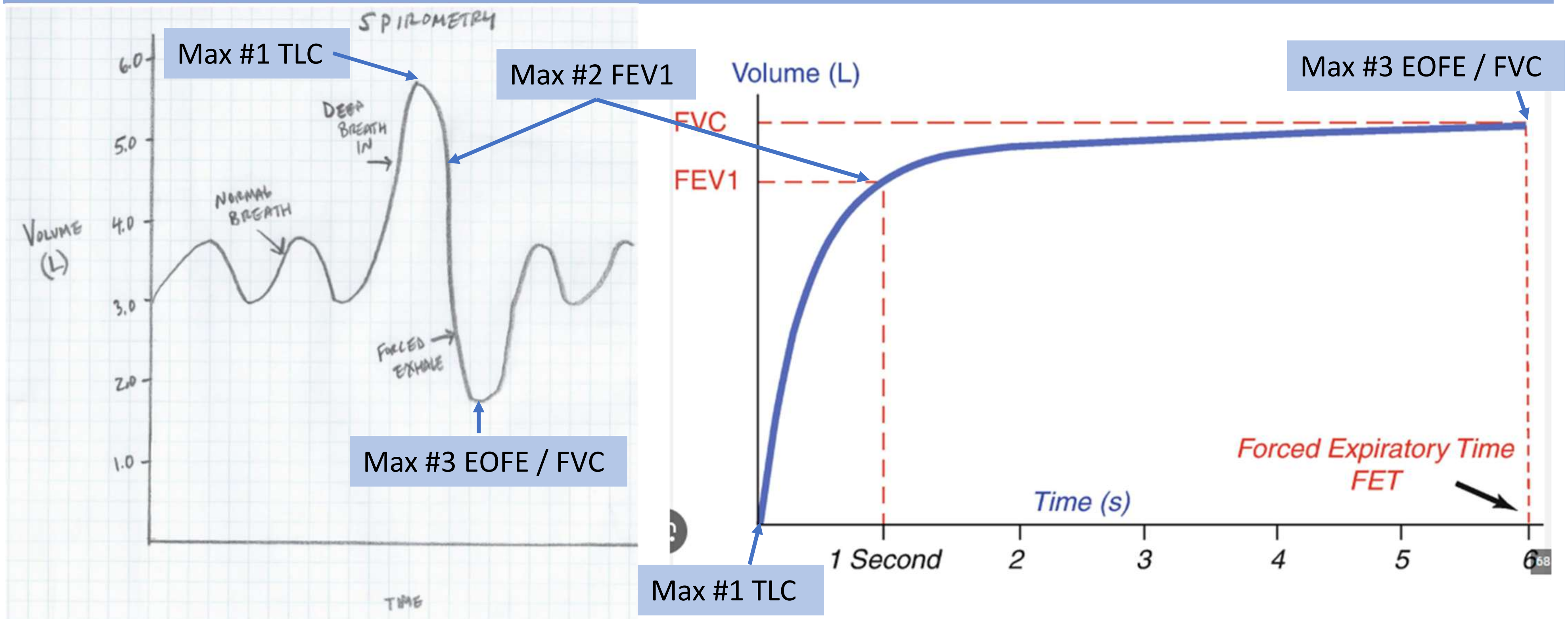
Maximum (#1) Inspiration - TLC

Maximum (#4) Inspiration – FIVC

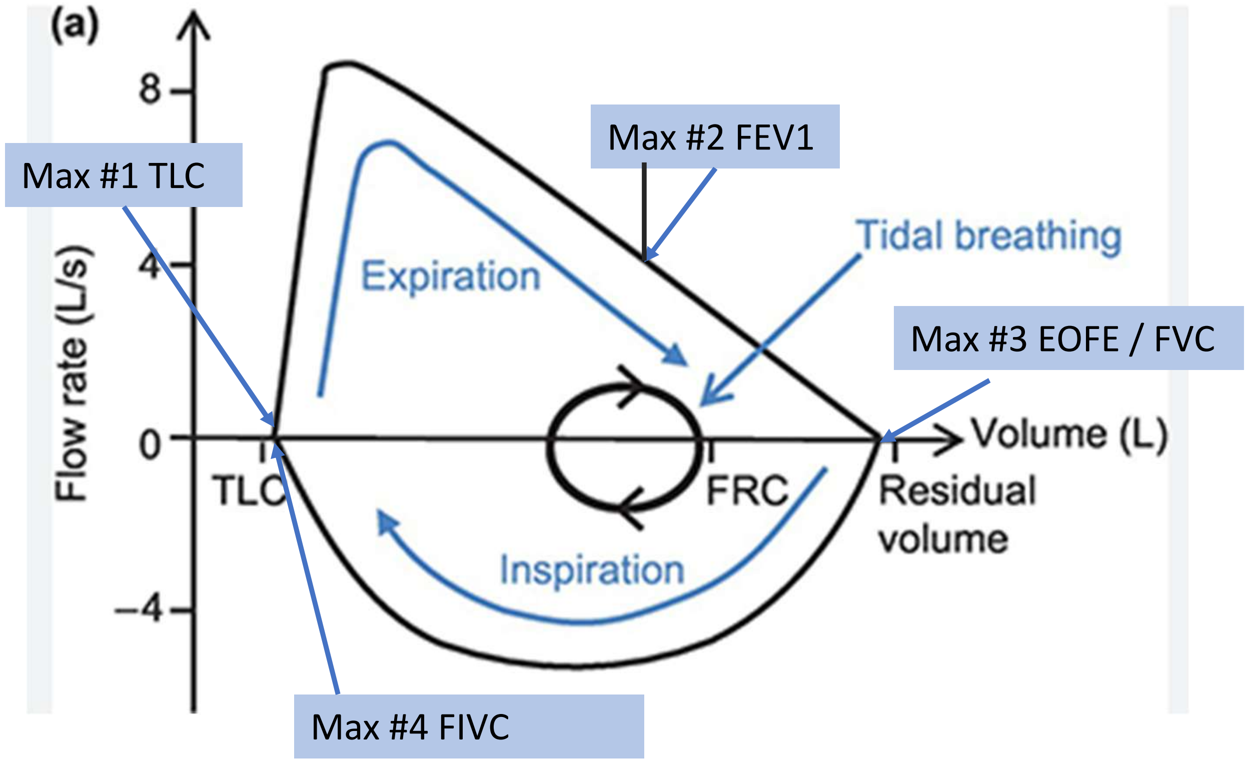


Maximum (#3) End Of Forced Exhalation (EOFE) – FVC

4 Maximums: Volume – Time Displays



4 Maximums: Flow Volume Loop



Learning Objectives

At the conclusion of this presentation
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2. explain **4 Maximums** within the forced vital capacity maneuver
    - as part of the spirometry procedure

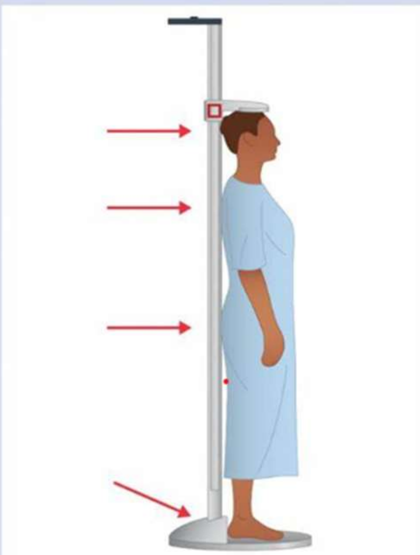
4 Maximums as part of the:

Spirometry Procedure

- Prepare the patient
- Instruct & Demonstrate
- Coach
  - Inspiratory & expiratory
  - Expiration-only devices

Procedure - Prepare the Patient: Height **is CRITICAL**

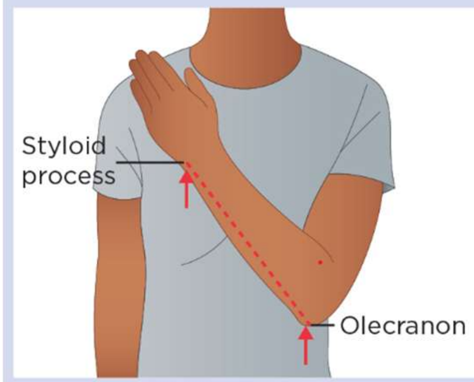
Fig 1. **Standing height**



The back of the head, shoulder blades, buttocks and heels should touch the stadiometer

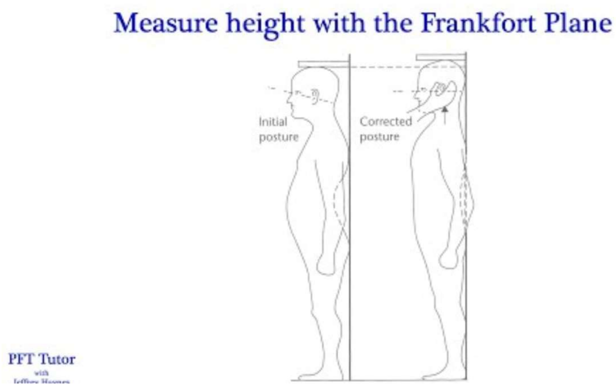
- The height must be measured against a wall or **stadiometer** - **without shoes!**

Fig 2. **Ulna length**



Measure from the olecranon process of the elbow to the midpoint of the styloid process of the wrist

Procedure - Prepare the Patient: Height is CRITICAL



PFT Tutor with Jeffrey Haynes: Height Measurement for Pulmonary Function Testing - YouTube (6:28)

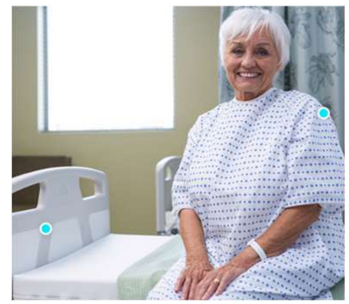
Key Points

- Height is key demographic used in reference equations, but it's really a substitute for chest dimensions
- It is important to record an accurate height
- Alternatives for standing height should be used in patients when standing height can not be measured or is affected by spinal abnormalities
- Stadiometers should be verified periodically

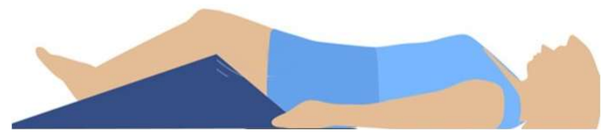
Procedure - Prepare the Patient: Patient Posture while testing is Critical

Sit tall; stay tall

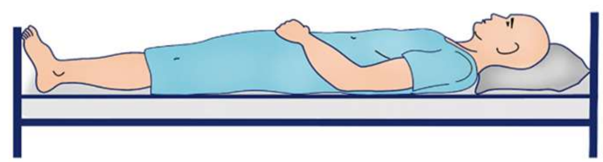
Standing



Semi-Fowler's



Crook's



Supine

Procedure - Instruct & Demonstrate: Four Within Maneuver Maximums

- **"BIG BREATH in fast, all the way to a completely full lung"**

Maximum **(#1)** Inspiration - TLC

- **"BLAST OUT hard and fast; use all the force possible"**

Maximum **(#2)** Blast out – FEV1

- **"KEEP BLOWING, keep blowing out all your air"**

Maximum **(#3)** Exhalation - EOFE / FVC

- **"BIG BREATH in fast, all the way to a completely full lung"**

Maximum **(#4)** Inspiration - FIVC

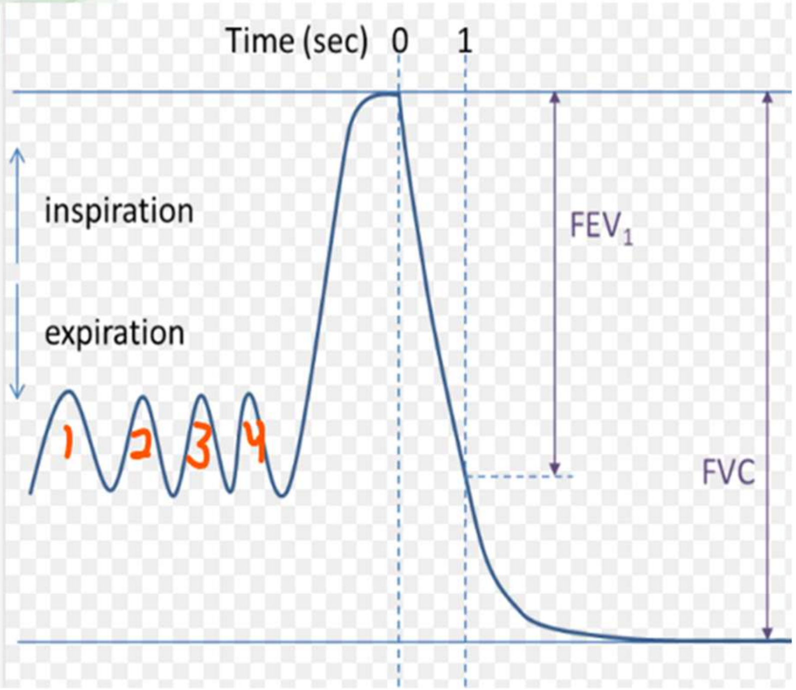
Procedure – Coach:

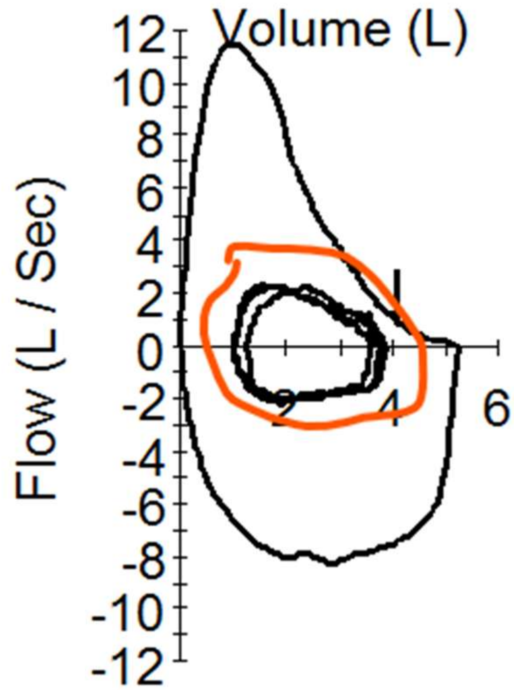
Maneuver

- “Sit tall; stay tall”
- “Mouthpiece & nose clip”
- “Normal breathing”
- “Deep breath IN…more…more”
- “BLAST hard”
- “Keep breathing out…out…out”
- “Deep breath back in”

Procedure - Coach Maneuver: Posture, “Mouthpiece & Nose clip”

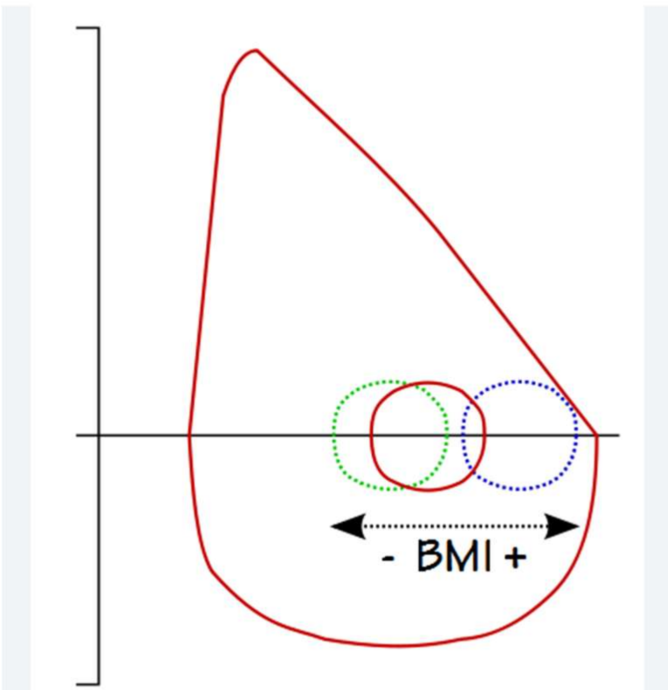
Procedure - Coach Maneuver:
"Normal Breathing"



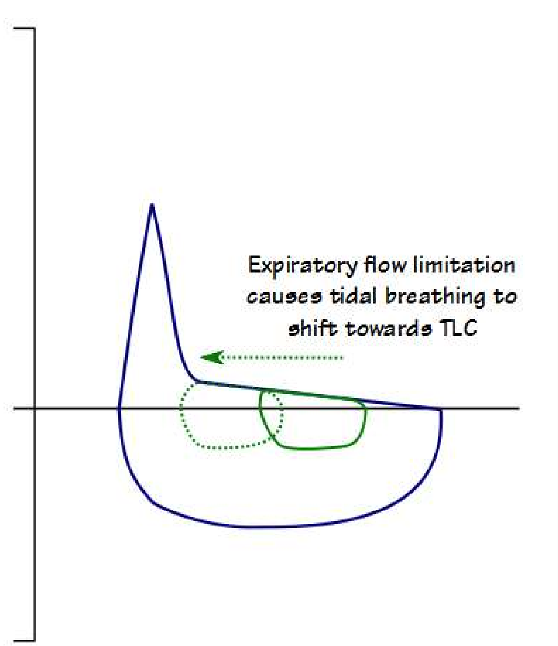


Note: FVL & Tidal breath

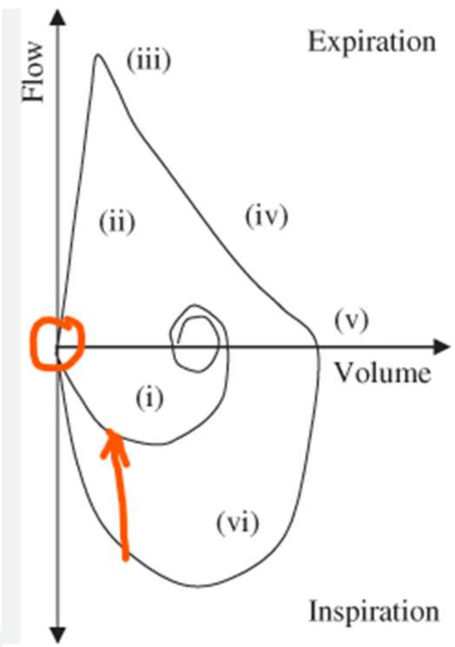
BMI

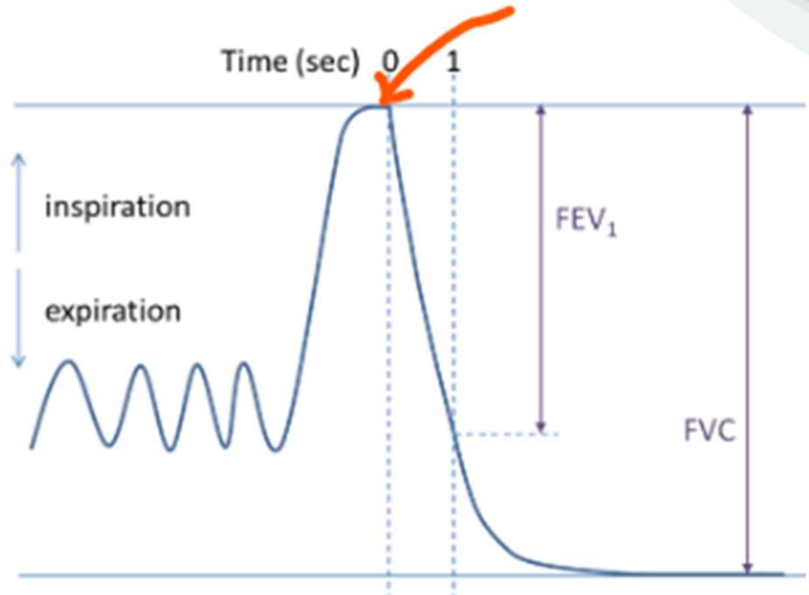


Expiratory Flow Limitation

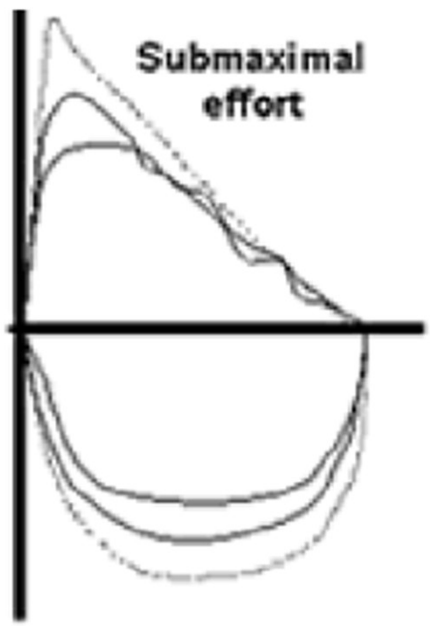


Procedure - Coach Maneuver: "Deep Breath IN" Max (#1) - TLC



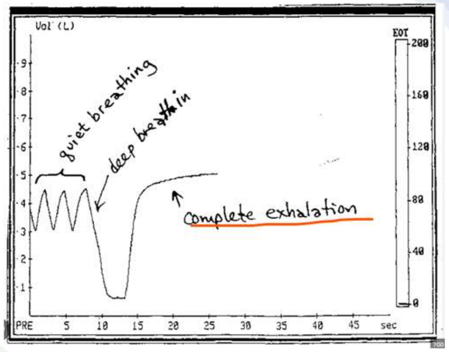


Procedure - Coach Maneuver: "Blast Hard" Max (#2) – FEV1

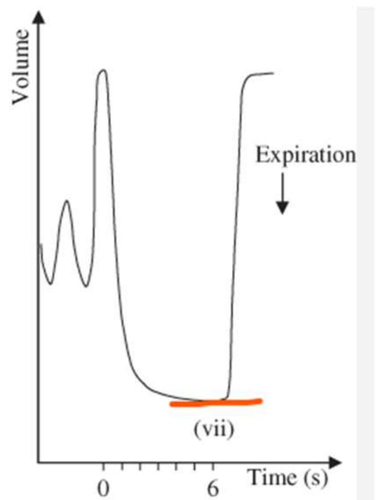


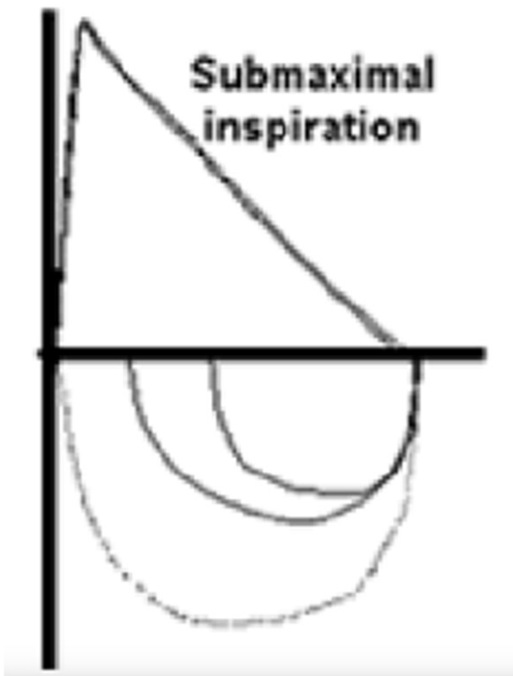
- **"Blast out hard"** – FEV1
  - Not just "Blow"
  - Blast with maximal effort / Hard / Fast
  - Stay sitting up straight; do not lean forward or put head/chin down
- Looking for **maximal effort** evidenced by a sharp peak in Flow-Volume loop
  - very early *(shifted left / close to the Y-axis)*
- Don't want a **sub-maximal** effort evidenced by a rounded peak or shifted right
  - should be discarded
- but **never discard the first blow** – it may be the best that you get!

Procedure - Coach Maneuver:
"Keep breathing out…"
Max (#3) EOFE / FVC



- **"keep blowing, keep blowing, keep blowing…"**
- EOFE
  - Plateau ≥ 1 second
    - Plateau defined as < 0.025 L/sec change
  - Forced Expiratory Time (FET) ≥15 seconds
    - Watch for: light-headedness, syncope
  - No plateau & < 15 seconds
    - FVC repeatability criteria
  - No glottic closure
- FVC
- *OLD:*
  - *EOT*
  - *≥ 6 seconds*





Procedure - Coach Maneuver: "Deep breath back in" Max (#4) - FIVC

- **"Deep breath back in"**
- Ideally $F_IVC = F_EVC$
  - FIVC > FVC:
    - Pt may not have been at TLC before the blast – coach to take **"more… more"** before the blast
    - Pt may have leaked – make sure there are no leaks during inspiration or expiration either at the nose or the mouth. Verify no leaks in the circuit.
  - FIVC < FVC:
    - Coach pt to take their last "**Breathe in FAST and DEEP to full lung.**"

Procedure - Coach Maneuver: Expiration only devices

Learning Objectives

At the conclusion of this presentation
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2. explain **4 Maximums** within the forced vital capacity maneuver
    - as part of the spirometry **procedure**
    - as <u>within-maneuver</u> criteria for “**acceptability”** and “**usability”**

Recognizing a good-quality flow-volume loop during spirometry

"Quick look:
1.Up fast,
2.Peak flow,
3.Smooth curve,
4.Back to zero."

1. **Rises almost straight up along the Y-axis** → rapid start of exhalation with minimal hesitation.
2. **Has a clear peak** → a distinct Peak Expiratory Flow (PEF)
3. **Smooth contour** → no cough, glottic closure, variable effort, or artifact.
4. **Returns to the X-axis** → exhalation continues until flow reaches zero, indicating a complete maneuver.

4 Maximums – “Within-Maneuver”

Acceptability

Criteria were developed as objective measures to determine:

- whether a maximal effort was achieved and
- acceptable FEV1 and/or
- acceptable FVC measurements were obtained.

Usability

Although the FEV1 and/or FVC measurements may not be technically acceptable, they may be clinically useful (i.e., “usable”)

Within-Maneuver Acceptability: - vs - Usability

Table 7. Summary of Acceptability, Usability, and Repeatability Criteria for FEV_1 and FVC

	Required for Acceptability		Required for Usability	
Acceptability and Usability Criterion	**FEV_1**	**FVC**	**FEV_1**	**FVC**
Must have BEV ≤5% of FVC or 0.100 L, whichever is greater	Yes	Yes	Yes	Yes
Must have no evidence of a faulty zero-flow setting	Yes	Yes	Yes	Yes
Must have no cough in the first second of expiration*	Yes	No	Yes	No
Must have no glottic closure in the first second of expiration*	Yes	Yes	Yes	Yes
Must have no glottic closure after 1 s of expiration	No	Yes	No	No
Must achieve one of these three EOFE indicators:	No	Yes	No	No
1. Expiratory plateau (≤0.025 L in the last 1 s of expiration)				
2. Expiratory time ≥15 s				
3. FVC is within the repeatability tolerance of or is greater than the largest prior observed FVC†				
Must have no evidence of obstructed mouthpiece or spirometer	Yes	Yes	No	No
Must have no evidence of a leak	Yes	Yes	No	No
If the maximal inspiration after EOFE is greater than FVC, then FIVC − FVC must be ≤0.100 L or 5% of FVC, whichever is greater‡	Yes	Yes	No	No

4 Maximums: Within-Maneuver "Acceptability" Max #1) TLC

- Starting from
  - end of normal tidal exhalation or
  - resting expiration level or
  - FRC level
- Rapid inspiration, ≤2 sec, to TLC level
- Maximal volume
- Max #1) TLC, is best verified by matching it with the Max #4) FIVC after the FVC maneuver.

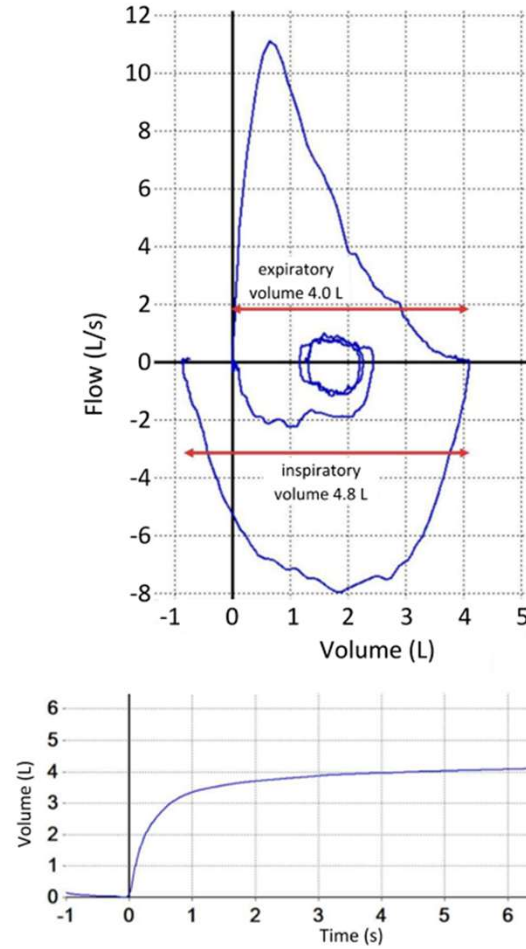
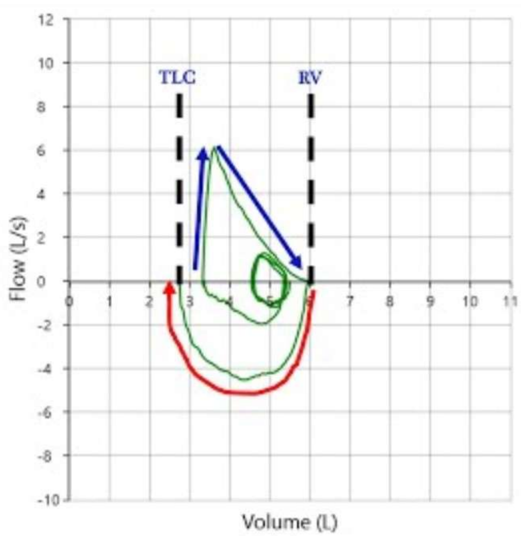
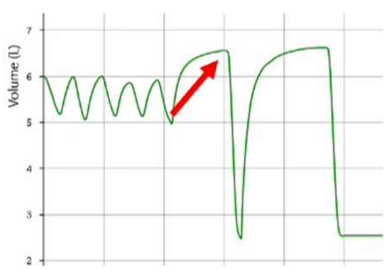


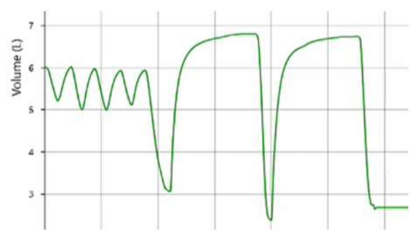
Figure E10. When the inspiratory volume at the end of the maneuver exceeds the forced expiratory volume, the subject did not reach total lung capacity before blowing out. The maneuver is not acceptable if the inspiratory volume exceeds the FVC by more than 0.100 L or 5% of FVC, whichever is greater. In this example, neither FEV_1 nor FVC is acceptable. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

4 Maximums: Within-Maneuver "Acceptability"
Max #1) TLC



PFT Tutor





"Submaximal Inhalation Error"   FIVC > FEVC

Key Points

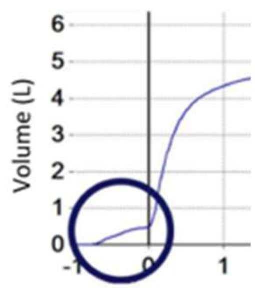
- Submaximal inhalation error is common
- FVC and FEV_1 can be markedly affected
- Sometimes it's the technologist's fault if the command to forcefully exhale is given prior to full inhalation
- Emphasize the importance of inhaling fully prior to starting spirometry

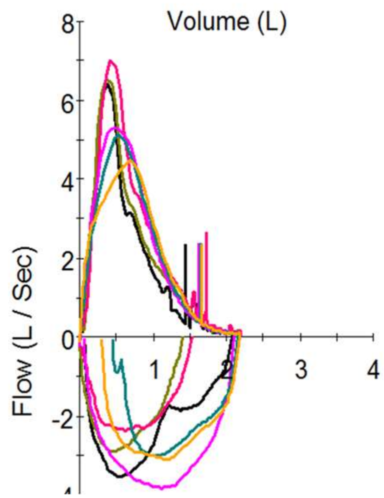
PFT Tutor with Jeffrey Haynes: Submaximal Inhalation Error During Spirometry Testing (14:16)

4 Maximums: Within-Maneuver “Acceptability”
Max #2) FEV1

START of FEV1 Blast

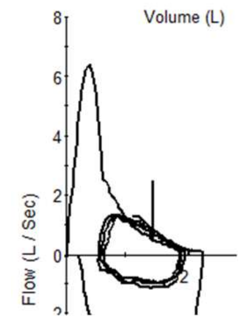
- Back Extrapolation (BEV) - **Time Zero**
  - Delayed Start / Hesitation
    - < 2 Seconds
  - False Start / Leak
- BEV < 5% or 0.1 L
  - Whichever is greater

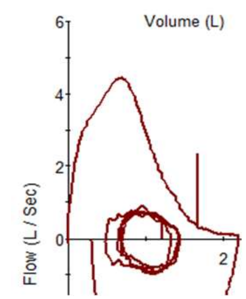




PEAK of FEV1 Blast

- Rise Time
  - < 150 ms
  - 10% - 90%
- Sharp peak, shifted left, close to Y-axis – **maximal effort**
- Rounded peak, shifted right, far from Y-axis – **sub-maximal effort**





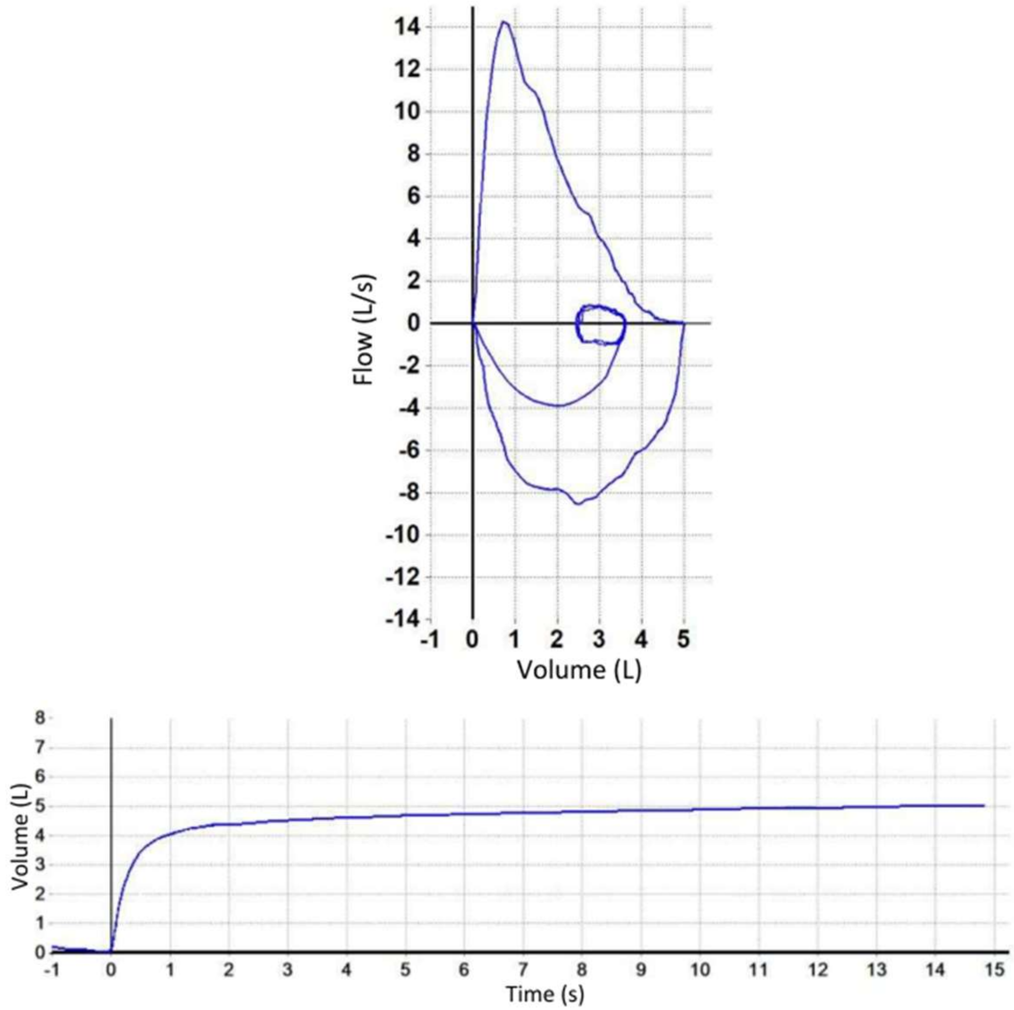


Figure E1. An acceptable maximal maneuver by a normal male (age 68.4 yr). The flow-volume graph has a fast start and sharp peak with a smooth drop to zero flow. There is a steep slope at the start of the volume-time curve with a plateau at the end of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

4 Maximums: Within-Maneuver "Acceptability"

Max #2 FEV1 – Start of FEV1 Blast:

Delayed Start Hesitation > 2 sec

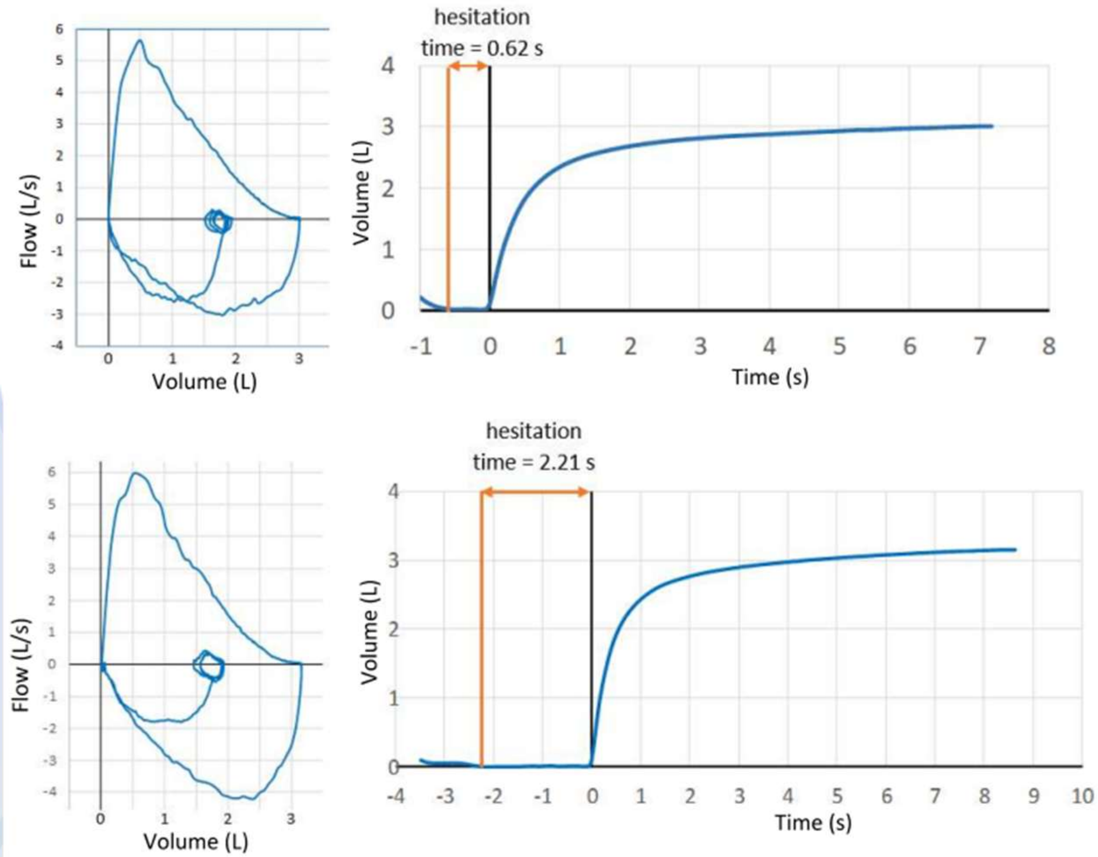
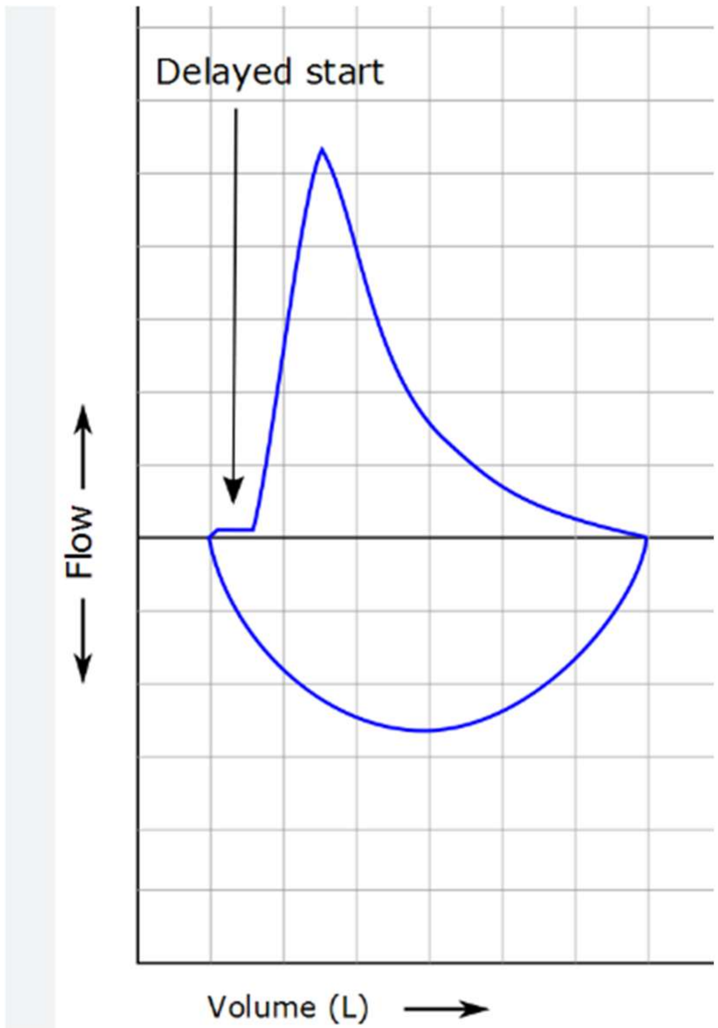


Figure E13. Hesitation time is defined as the time from attaining maximum inspired lung volume to the back-extrapolated time zero which should be less than 2 s. The upper panel shows an acceptable maneuver with a hesitation time of 0.62 s. The lower panel shows a maneuver from the same person but with a hesitation time of 2.21 s which should generate a warning and a message to instruct the patient to blast out immediately when completely full.


Delayed start
Flow
Volume (L)

4 Maximums:
Within-Maneuver
"Acceptability"

Max #2 FEV1 –
Start of FEV1 Blast:

False Start
Leak </> 5% or 0.1 L
(*whichever is greater*)

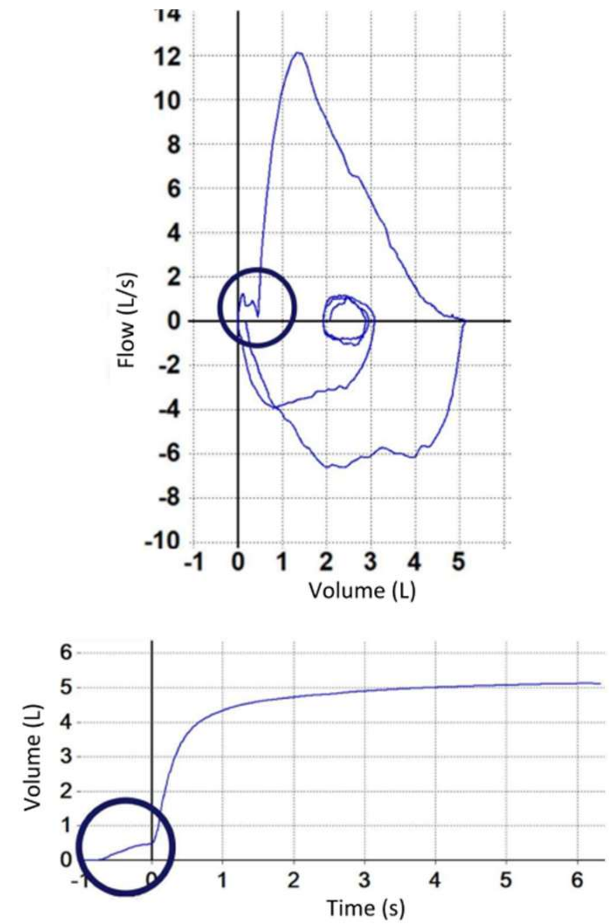


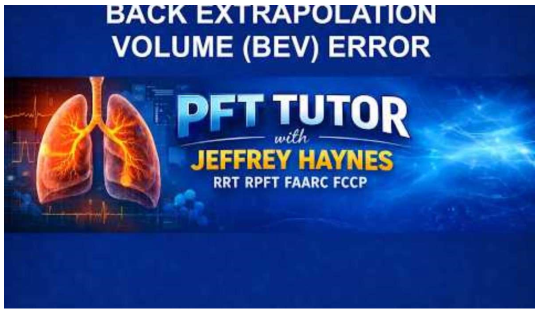
Figure E8. A false start occurs when the subject reaches total lung capacity and leaks out some air before beginning a forced expiration. In this example the back extrapolated volume is 0.475 L which exceeds 5% of FVC and therefore the FVC and FEV_1 are unacceptable. *(reproduced with permission – RESPTREC^{TM} Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

4 Maximums: Within-Maneuver “Acceptability”
Max #2 FEV1 – Start: Back Extrapolated Volume (BEV)

Must have BEV <5% of FVC or
< 0.1 L, whichever is greater

FVC 2.0 L x 0.05 = 0.100 L ….SO….. If FVC ≤ 2.0 than BEV < 0.1 L

4 Maximums: Within-Maneuver "Acceptability"
Max #2 FEV1 – Start: BEV



PFT TUTOR with Jeffrey Haynes: Back Extrapolation Volume (BEV) Error (8:43)

Key Points

- Excessive back extrapolated volume occurs when the patient lets some air leak out before performing the forced expiratory maneuver
- >100 ml or 5% of the FVC is unacceptable
- Excessive BEV may cause a falsely higher FEV1
- BEV can be identified with software alerts and inspection of the F/V loop and volume/time curve
- This is usually a correctable problem with good coaching

4 Maximums: Within-Maneuver "Acceptability"
Max #2 FEV1 – Start: BEV

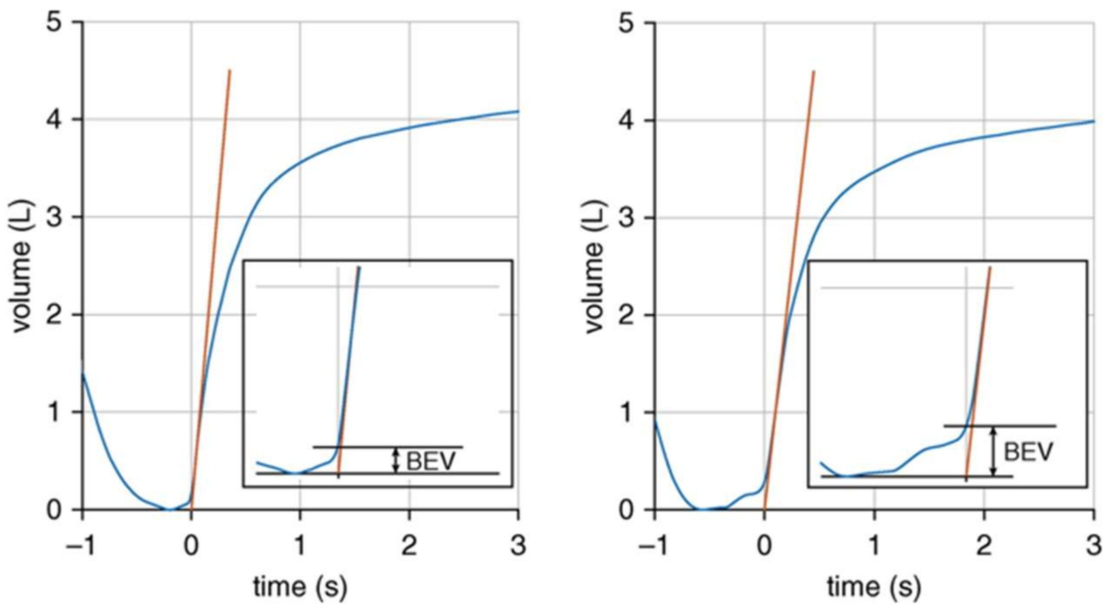


Figure 1. Back-extrapolated volume (BEV). Time 0 is found by drawing a line with a slope equal to peak flow through the point of peak flow (red line) on the volume–time curve and setting Time 0 to the point where this line intersects the time axis. The BEV is equal to the volume of gas exhaled before Time 0 (inset), which, in these two examples from the same patient, is 0.136 L for the left panel (acceptable) and 0.248 L for the right panel (unacceptable). For this patient, the BEV limit is 5% FVC = 0.225 L.

Am J Respir Crit Care Med, 2019

Breeze - [Patient - QUIROGA DE CABRERA, BARBARA; Visit - 5/16/2024 2:24:39 PM]

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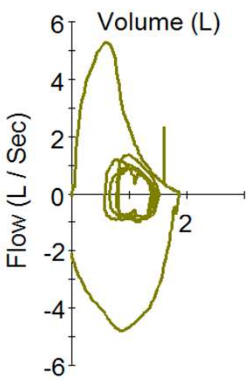
Calibrate Zero Flow Start Stop 00:00:00 Pre

Time	Select	I-Lp	Test Mode	ATS	ATS	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute	FEV1 % Predicted	absolute
Predicted						3.04		2.44		81	2.46		6.00						
Pre																			
14:28:40						1.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11	68	
14:29:03	✓					1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08	68	
14:30:39	✓					1.92	63	1.64	-1	85	2.04	82	4.94	82	6.33	-15	0.09	67	
14:28:19	✓					1.87	61	1.62	-2	87	2.01	81	5.32	88	5.55	-8	0.11	66	
ATS			Pre/Baseline		AA	1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08	68	

14:28:19



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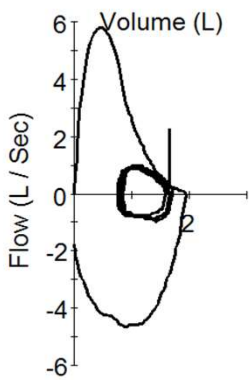

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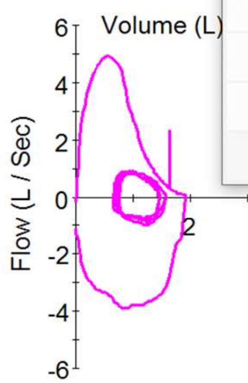


Calculator

Standard

0

MC MR M+ M- MS M˅

% √ x^2 ¹⁄ₓ

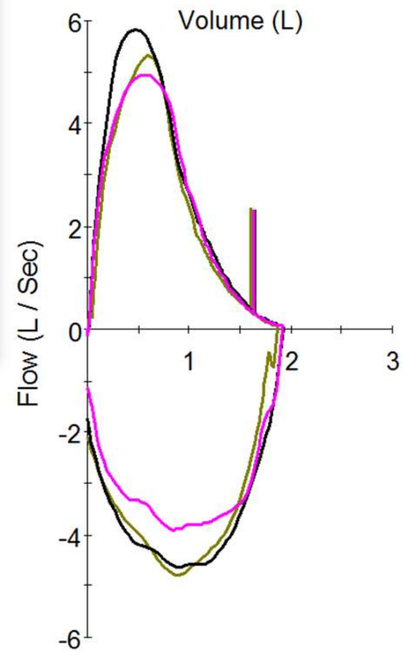
CE C ⌫ ÷

7 8 9 ×

4 5 6 −

1 2 3 +

± 0 . =



Patient Trend Visit Protocol / Log FVC SVC Pleth DLCO FRC (N2) MVV SBN2 ABG GX RPM PF Pages Disability BRP Trend

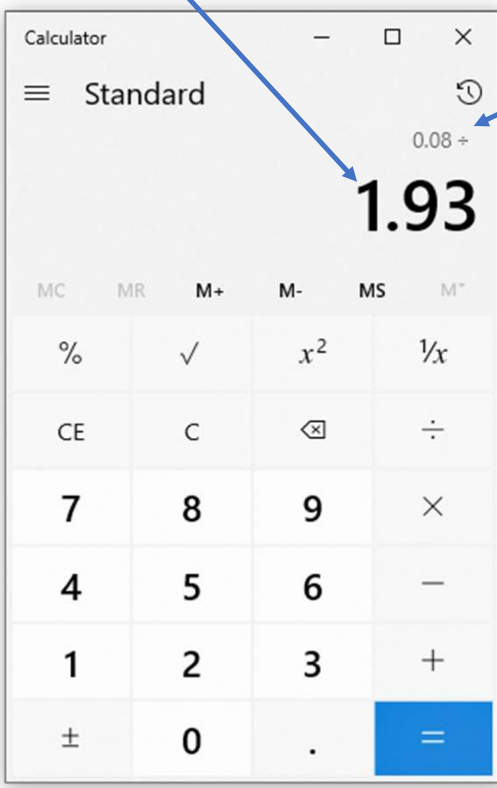
Ready Shared Only

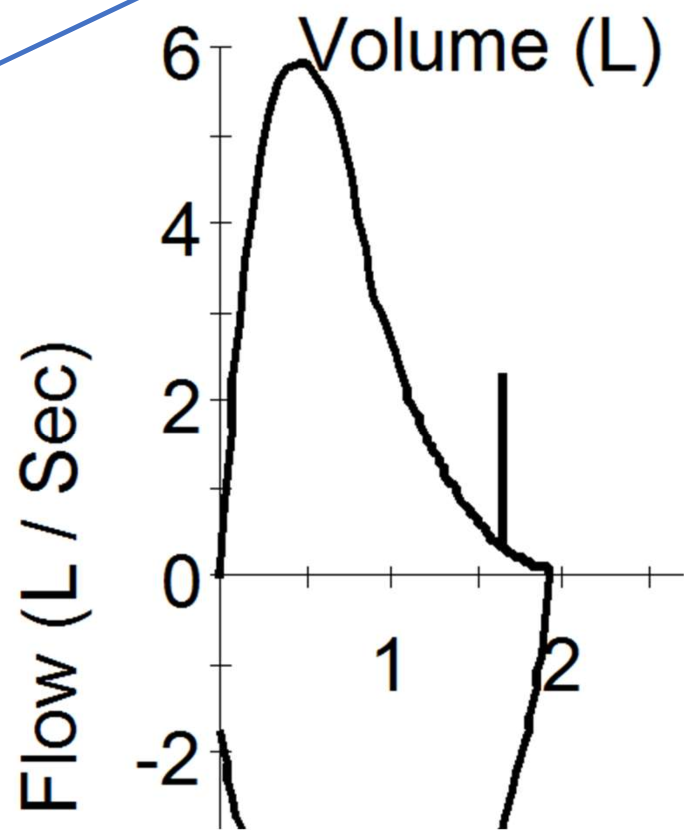
Type here to search

12:16 PM 5/17/2024

ATS												
	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute
	3.04		2.44		81	2.46		6.00				
	1.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11
	1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08
	1.92	63	1.64	-1	85	2.04	82	4.94	82	6.33	-15	0.09
	1.87	61	1.62	-2	87	2.01	81	5.32	88	5.55	-8	0.11
AA	1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08

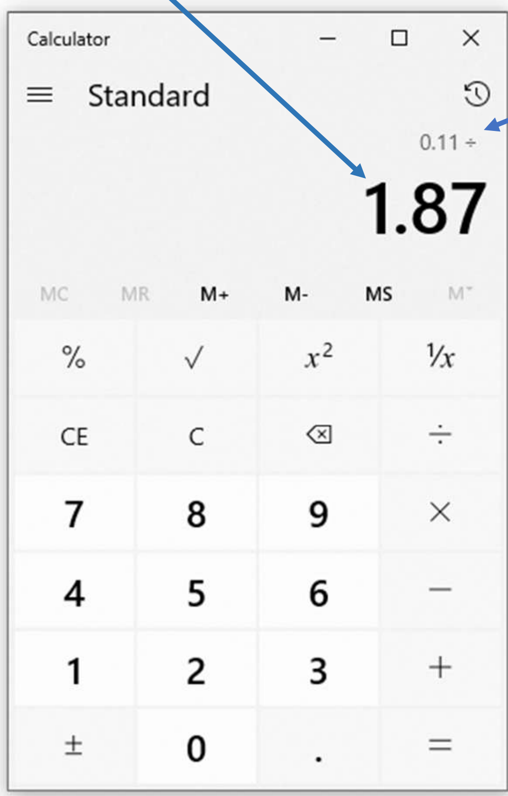
0.08 ÷ 1.93 = 0.04145 X100 = 4.1% 4.1% < 5% Acceptable BEV

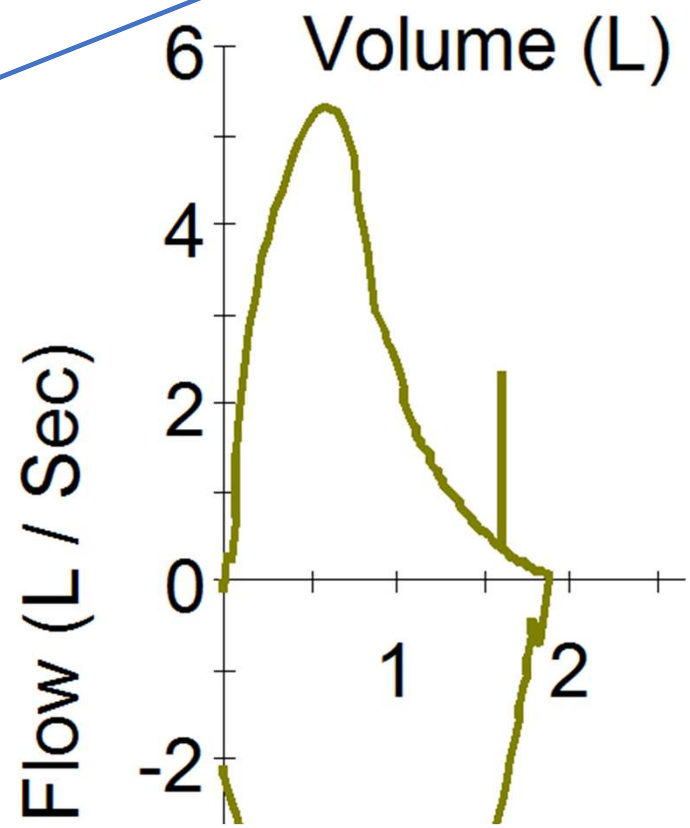




ATS	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute
	3.04		2.44		81	2.46		6.00				
	1.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11
	1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08
	1.92	63	1.64	-1	85	2.04	82	4.94	82	6.33	-15	0.09
	1.87	61	1.62	-2	87	2.01	81	5.32	88	5.55	-8	0.11
AA	1.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08

0.11 ÷ 1.87 = 0.05882   X 100 = 5.8%   5.8% > 5%   Unacceptable BEV





4 Maximums: Within-Maneuver "Acceptability"
Max #2 FEV1 – Start: BEV

Must have <u>BEV ≤5% of FVC or 0.100 L,</u> whichever is greater

Yes, required for both Acceptability and Usability for both FEV1 & FVC

Graph must include both:
(starts at or before the earlier)

- 1 sec before the "0" (PEF Slope back extrapolated)
- Peak of Inspiration - TLC / Maximal Inspiration line

BEV value must be shown in % FVC and in Liters

Rise Time

- 10% - 90%
- ≤ 150 ms
- May be > 150 ms with upper airway obstruction

Back Extrap Vol absolute
0.14
0.05
0.08
0.08
0.14

How can I coach my patient to avoid excessive back extrapolated volume?

- Ensure that there isn't a positive zero-flow error
- Start spirometry with tidal breathing on the mouthpiece
- Explain the error to the patient and show them graphically
- Instruct the patient to "blast" the air out immediately
- Any pause at TLC should be < 2 seconds
- Analogy: "You're in a drag race but when the light turns green you're rolling a few feet before hitting the throttle"
- Allow the patient to do the maneuver on their own: "as soon as you feel completely full, blast it out immediately"

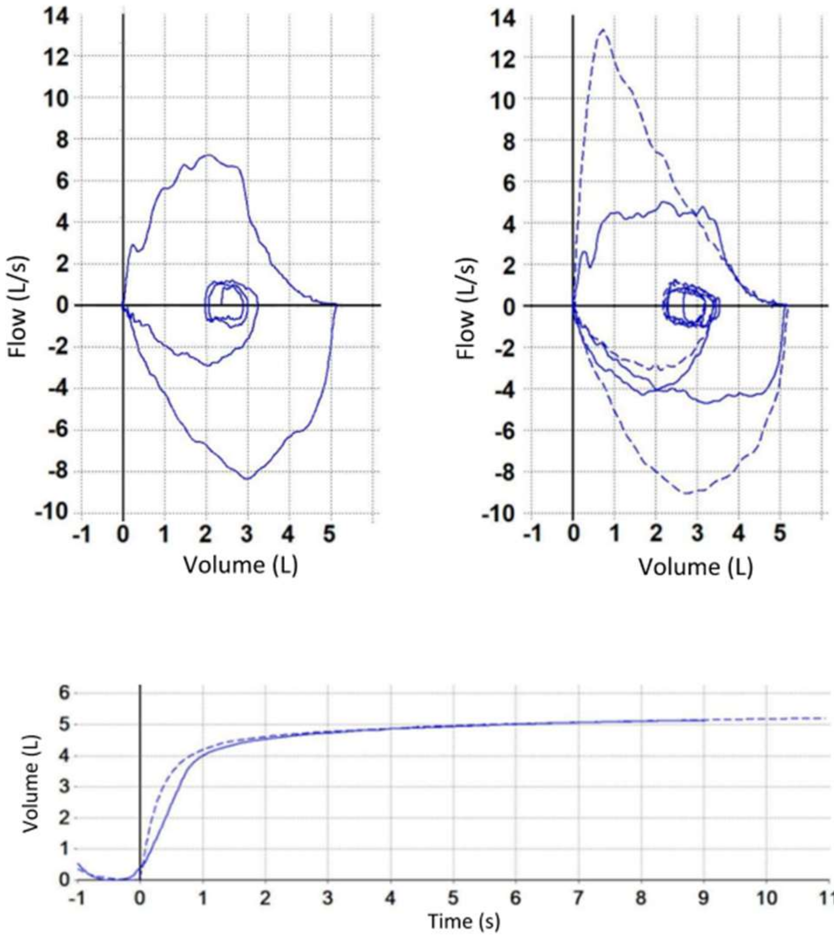
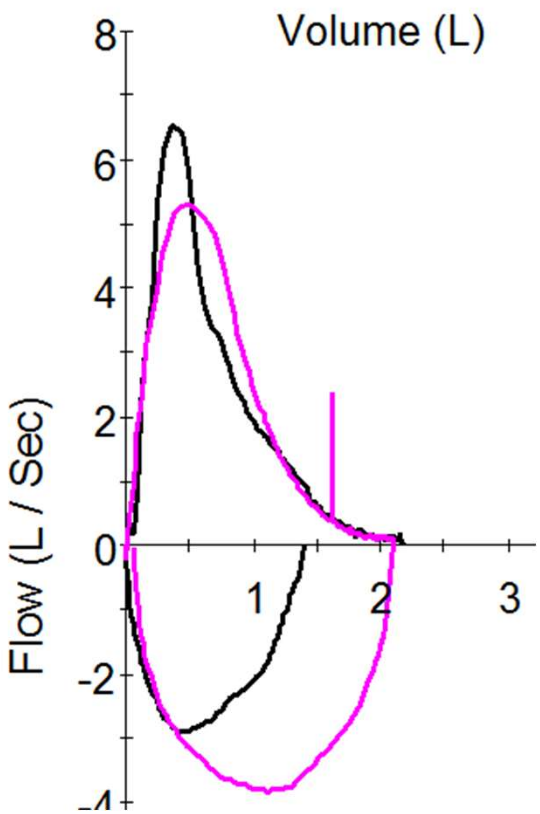


Figure E6. A sub-maximal effort is characterised by a rounded flow-volume curve and a less steep slope at the start of the volume-time curve. Compare a sub-maximal effort (solid line) to an acceptable maneuver (dashed line) in the same subject. A sub-maximal effort will often have a rise time >150 ms which will trigger a warning – see Section E8. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

4 Maximums: Within-Maneuver “Acceptability”

Max #2 **FEV1** – Peak

Rise < 150 ms



4 Maximums:
Within-Maneuver
“Acceptability”

Max #2 **FEV1** - Peak

Sub-Maximal Efforts

Effect of Effort on Measurement of Forced Expiratory Volume in One Second

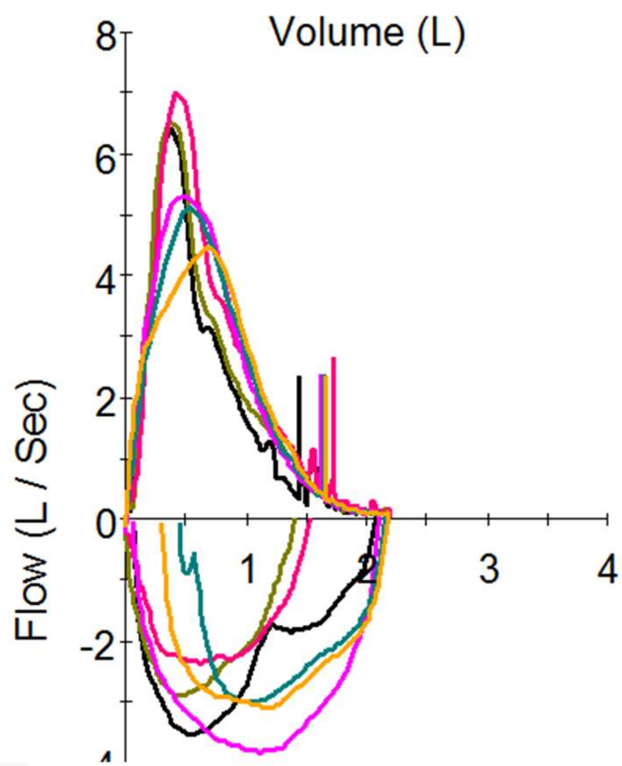
Michael J. Krowka , **Paul L. Enright** , **Joseph R. Rodarte** , and **Robert E. Hyatt**
https://doi.org/10.1164/ajrccm/136.4.829 **PubMed:** 3662235

Abstract | **Cited by** | **PDF**

The American Thoracic Society recommends that the largest FEV_1 be reported from a set of forced expiratory vital capacity maneuvers performed with maximal expiratory effort. However, increased expiratory effort can decrease the FEV_1. When we evaluated the peek expiratory flow rate (PEFR) in 5 normal subjects, measured from flow-volume curves, as a noninvasive index of expiratory effort, it was positively correlated with indices of effort obtained by using an esophageal balloon.

We then measured the difference ($dFEV_1$) between the largest FEV_1 and the FEV_1 from the maneuver with the highest PEFR during 10 test sessions in 10 normal subjects. Thus, $dFEV_1$ was always $\geqslant 0$. The mean $dFEV_1$ was 110 ml for all sessions but decreased to 80 ml when maneuvers with poorly reproducible PEFR or forced expiratory vital capacity values were discarded. We also reviewed 9,471 spirometry sessions from outpatients and found $dFEV_1$ to be greater than 50 ml in 28% of this population and greater than 151 ml in 7%.

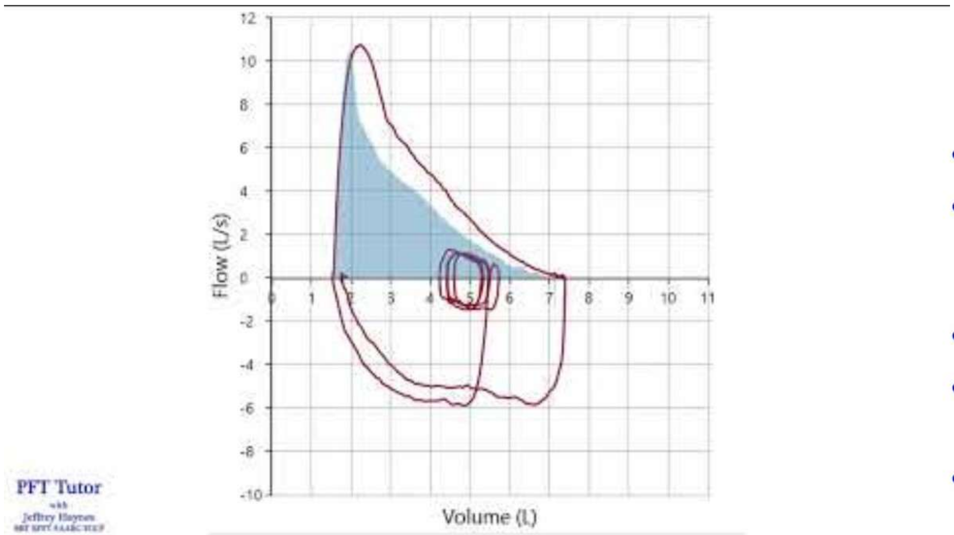
We concluded that during standard spirometry, FEV_1 is inversely dependent on effort. Maximal effort decreases FEV_1 because of the effect of thoracic gas compression on lung volume. we recommend that values from spirometry maneuvers that demonstrate submaximal effort, indicated by a decreased PEFR, be discarded. The flow-volume curve display of superimposed efforts facilitates the recognition of submaximal efforts.



Mayo Clinic

4 Maximums: Within-Maneuver "Acceptability"
Max #2 FEV1 - Peak

[PFT Tutor with Jeffrey Haynes: Should you always report the largest FEV1 in Spirometry Testing?](#) (5:42)



Key Points

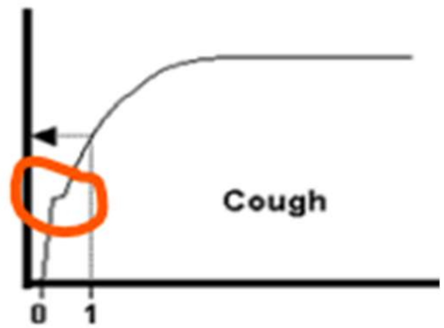
- FEV1 and FVC can be affected by submaximal PEFR
- Using the largest FEV1 from a spirometry maneuver with submaximal effort may hide a true bronchodilator response or create an overestimated response to a bronchial challenge test
- Be sure to coach the patient to "blast" the air out
- In most cases you should be able to obtain a spiked peak flow on the flow/volume curve
- The largest FEV1 is not always the true FEV1

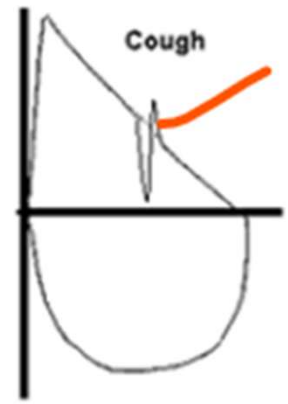
Within-Maneuver "Acceptability" Zero-Flow

- **Must have no evidence of a faulty zero-flow setting**
  - Yes, required for both Acceptability and Usability for both FEV1 & FVC
- Maneuvers conducted with an erroneous zero-flow level will either under- or overestimate FEV1 and FVC and render both FEV1 and FVC neither acceptable nor usable.

Within-Maneuver "Acceptability"
No cough in the first second of expiration

- **Must have <u>no cough in the first second of expiration</u>***
  - Yes, required for both Acceptability and Usability, but only for <u>FEV1</u>
  - No, not required for neither Acceptability nor Usability for <u>FVC</u>
- A cough during the first second of the maneuver can affect the measured FEV1 value, and the FEV1 from such a maneuver is neither acceptable nor usable.
  - However, the FVC may be acceptable.





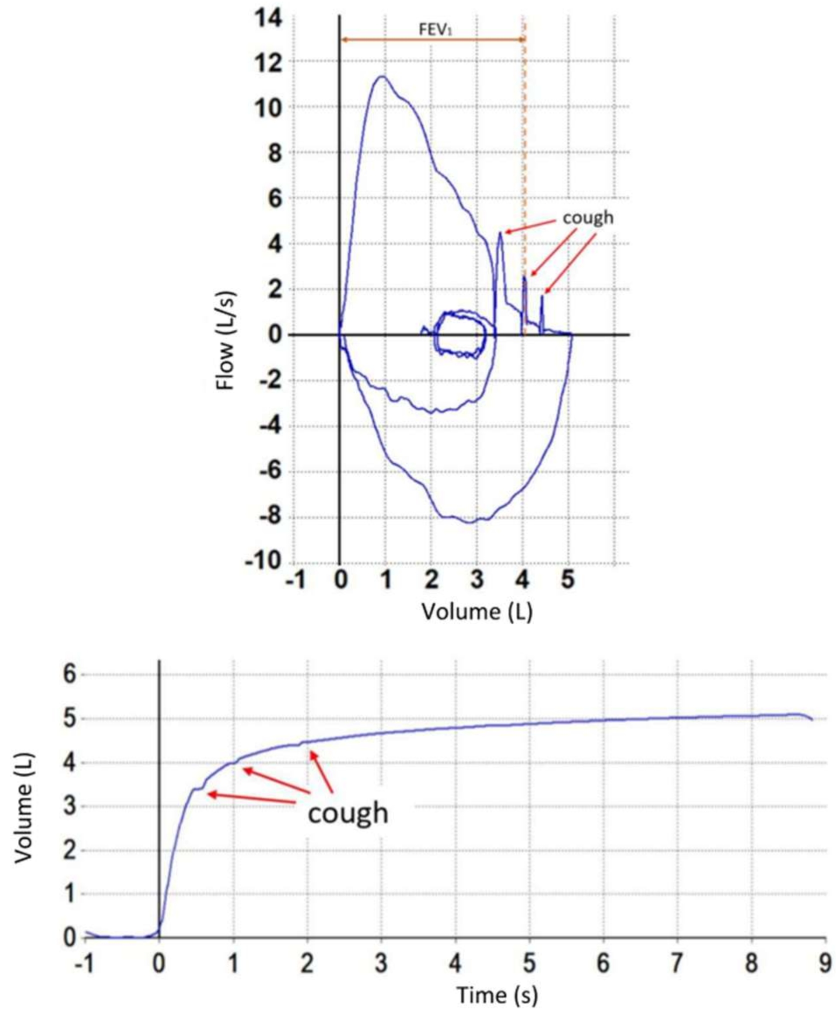


Figure E7a. A cough is seen as blips in the flow-volume graph. The volume-time graph shows that the initial cough occurred in the first second of expiration. The dashed orange line on the flow-volume graph is at the point of FEV_1 on the volume axis and more clearly shows that the initial cough occurred in the first second. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

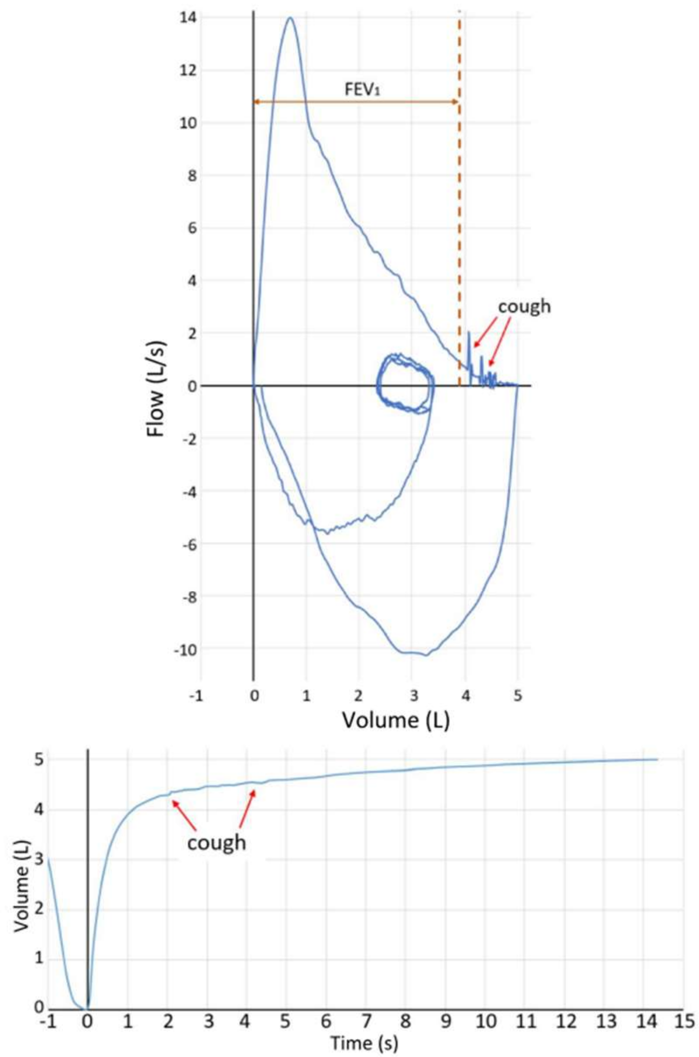
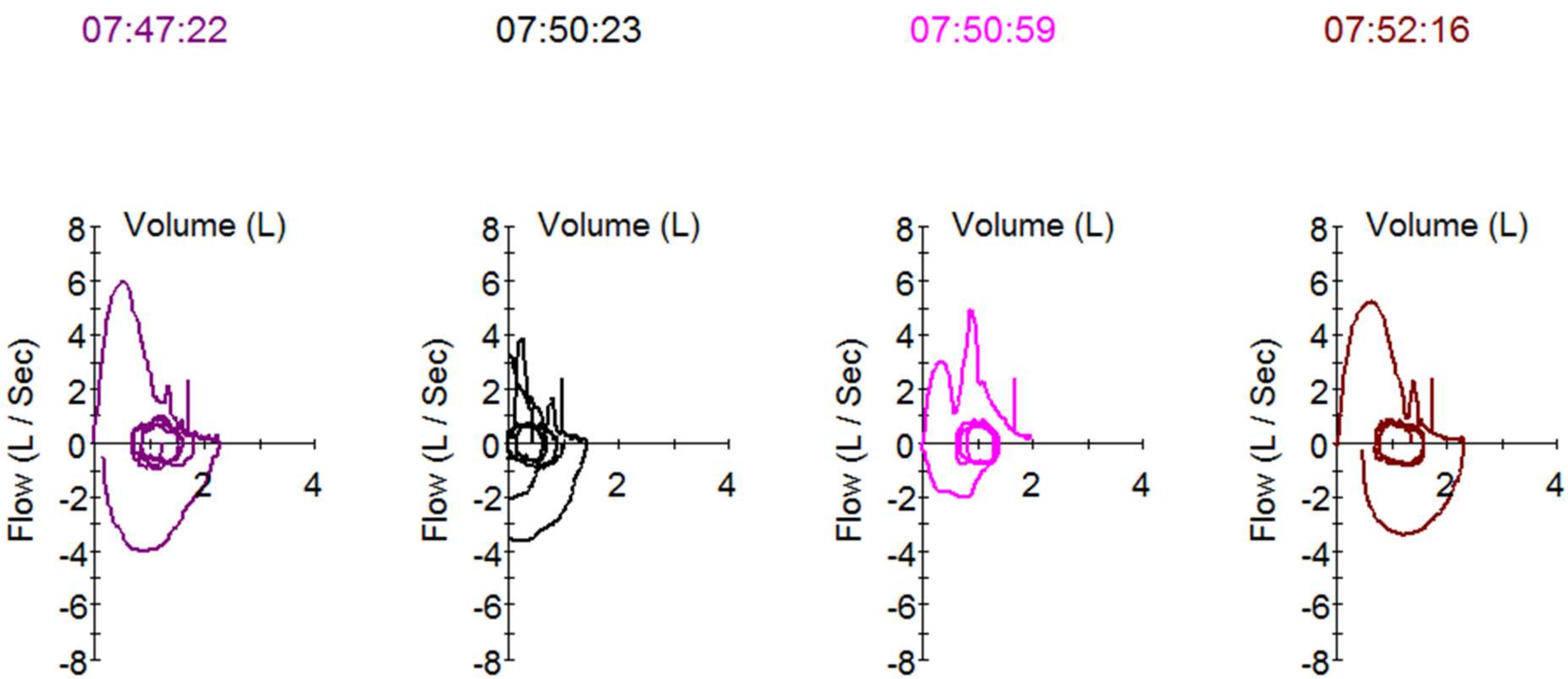
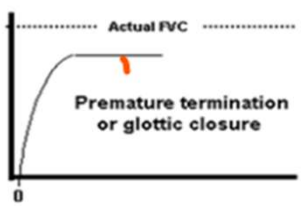


Figure E7b. A cough later in expiration. In this example, the volume-time graph does not clearly indicate the start of the cough. The dashed orange line at FEV_1 on the flow-volume graph shows that the cough occurred later than 1 s and thus the FEV_1 and FVC measurements are acceptable.


07:47:22
07:50:23
07:50:59
07:52:16
Volume (L)
Flow (L / Sec)
8
6
4
2
0
-2
-4
-6
-8
2
4

Within-Maneuver "Acceptability"
No Glottic closure
<u>in</u> the first second of expiration

- **Must have no glottic closure <u>in</u> the first second of expiration***
  - Yes, required for both Acceptability and Usability for <u>both</u> FEV1 & FVC
- *For children aged 6 years or younger, must have at least 0.75 seconds of expiration without glottic closure or cough for acceptable or usable measurement of FEV0.75.



Early termination
Glottic closure

4 Maximums: Within-Maneuver "Acceptability" Max #3) EOFE

- Continuing from FEV1
- Continuing to
  - EOFE
    - Plateau: ≥ 1 second
    - FET: ≥ 15 seconds
    - Repeatability
  - Maximal expiration level
- (Old guidelines – no longer used:
  - 6 seconds
  - "End of Test" / EOT)

Within-Maneuver "Acceptability" No Glottic closure <u>after</u> first second of expiration

- **Must have no glottic closure <u>after</u> the first second of expiration***
  - No, not required for neither Acceptability nor usability for FEV1
  - Yes, required for Acceptability for FVC
  - No, not required for Usability for FVC
- *For children aged 6 years or younger, must have at least 0.75 seconds of expiration without glottic closure or cough for acceptable or usable measurement of FEV0.75.

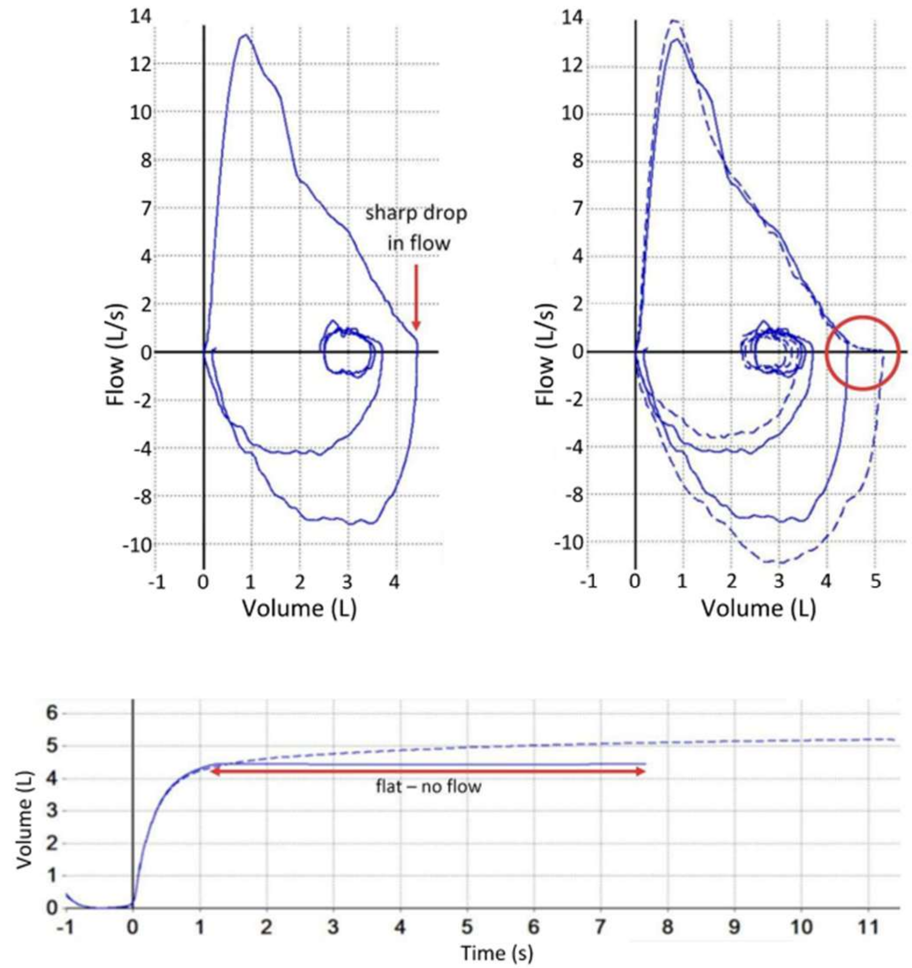


Figure E9. Glottis closure: note the sudden drop in flow in the flow-volume graph and the flat line after 1.25 seconds in the volume-time graph. Compare the glottis closure (solid line - FVC = 4.4 L) to an acceptable maneuver (dashed line - FVC = 5.2 L) in the same subject. In both cases, FEV_1 = 4.3 L. *(reproduced with permission – RESPTREC[TM] Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

Within-Maneuver "Acceptability"
End Of Forced Exhalation – EOFE

Old term – End of test (EOT); ≥ 6 seconds – no longer applies

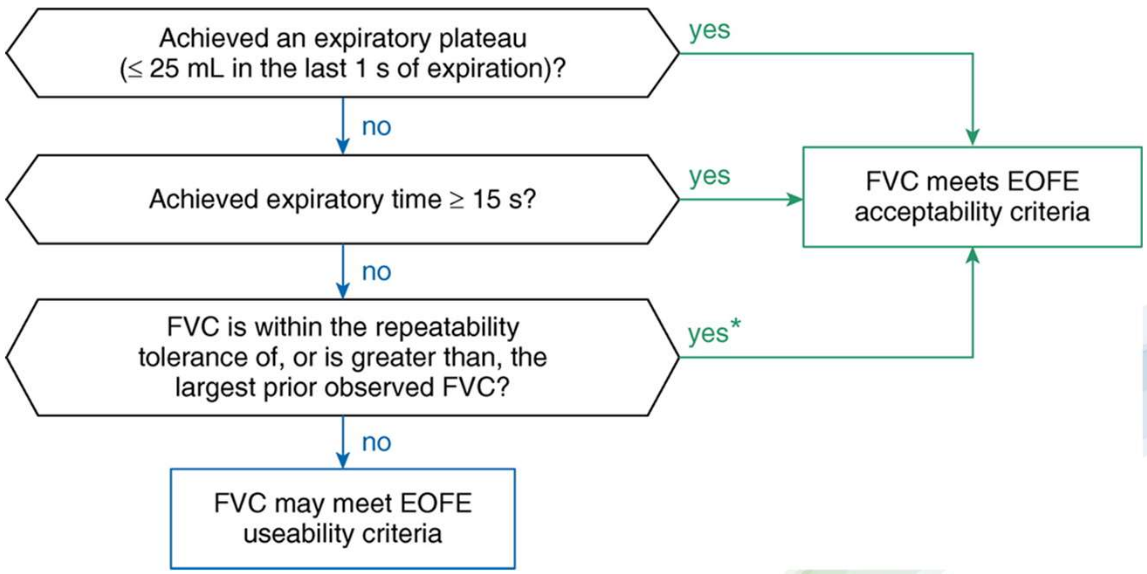
Plateau

- < 0.025 L/sec change
- ≥ 1 second

Forced Exhalation Time (FET)

- ≥ 15 seconds

FVC meets **repeatability** criteria



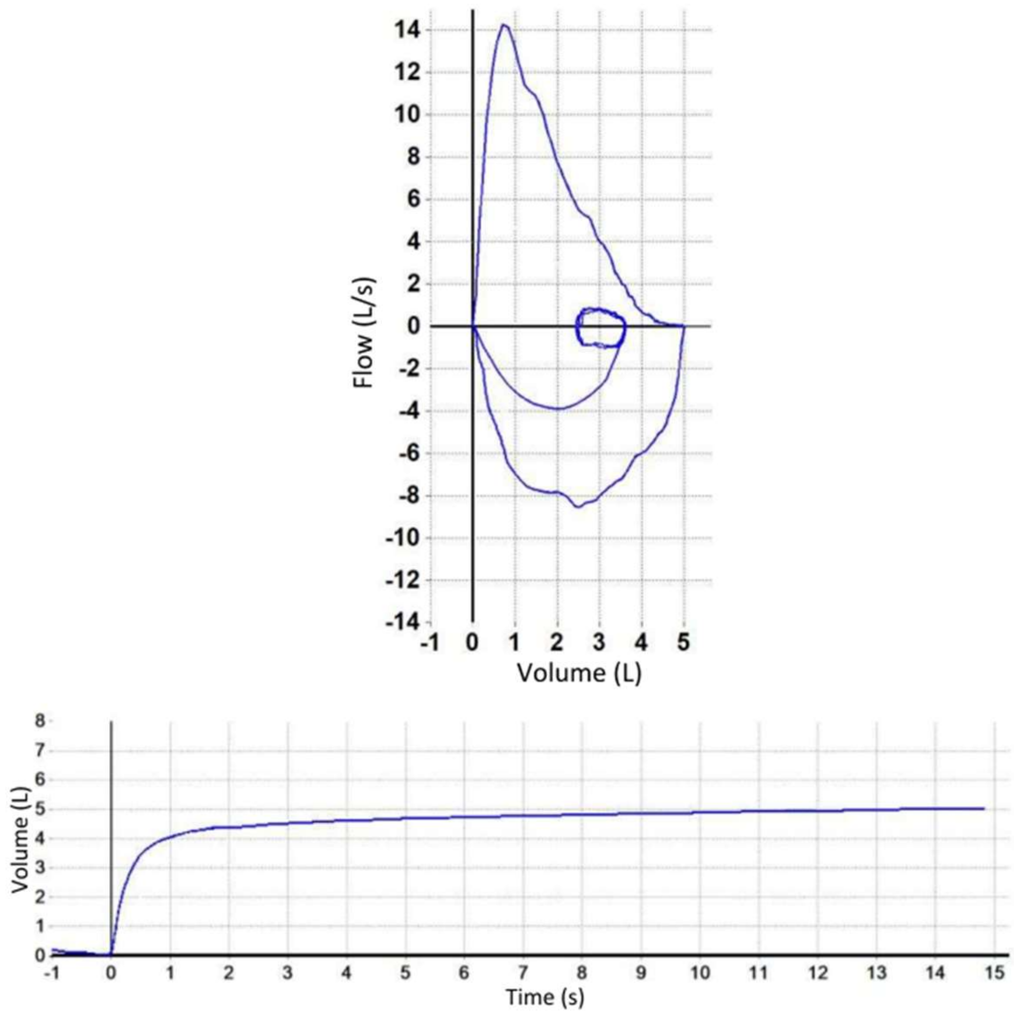


Figure E1. An acceptable maximal maneuver by a normal male (age 68.4 yr). The flow-volume graph has a fast start and sharp peak with a smooth drop to zero flow. There is a steep slope at the start of the volume-time curve with a plateau at the end of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

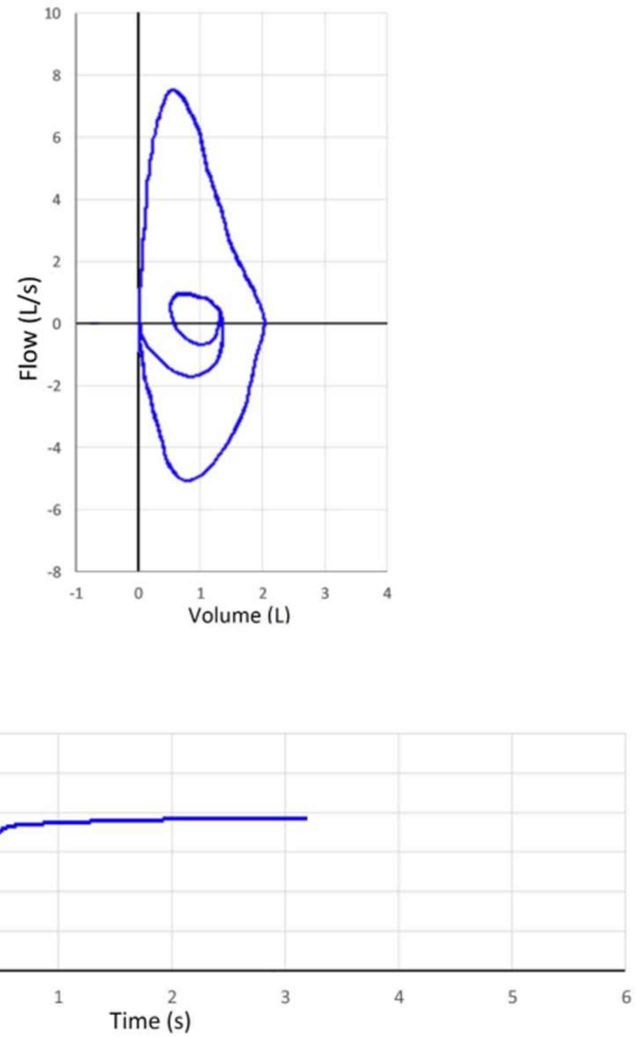
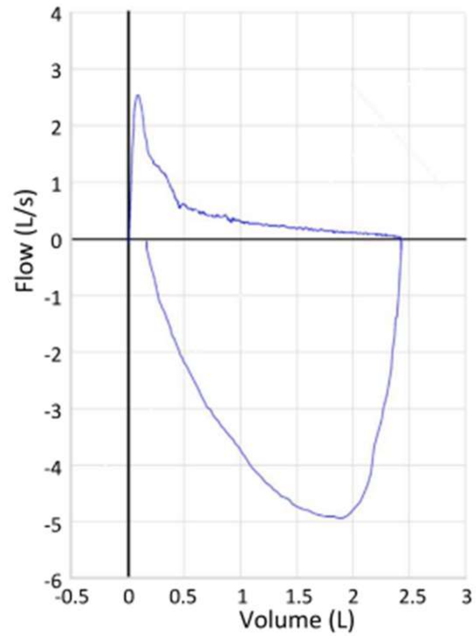


Figure E4. An acceptable maximal maneuver by a male (age 77.3 yr) with restrictive lung disease. Note that a plateau was reached in less than 3 s of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*



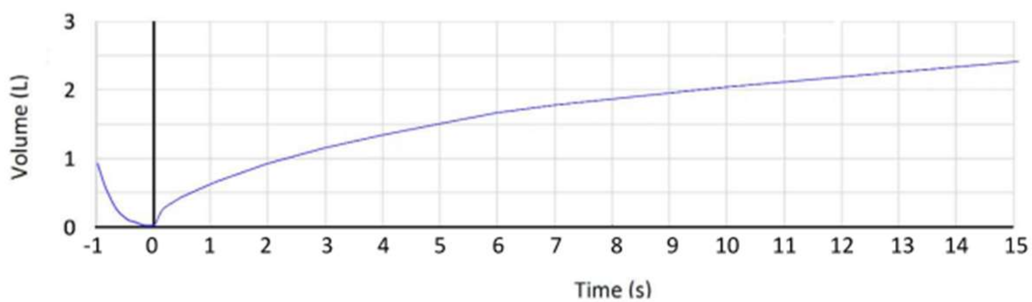


Figure E3. An acceptable maximal maneuver by a female (age 52.6) yr with very severe obstruction. Note that no plateau was reached by 15 s of expiration. *(reproduced with permission – RESPTREC^{TM} Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

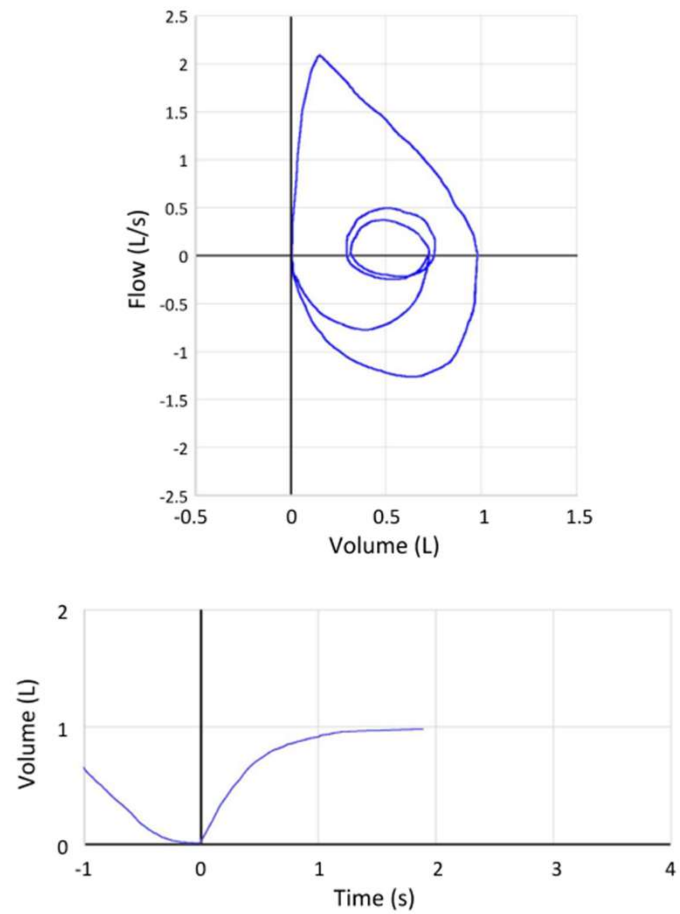


Figure E2. An acceptable maximal maneuver by a normal male (age 4.0 yr). Note the convex shape of the forced expiratory flow segment of the flow-volume curve which is often seen in healthy children with with high elastic recoil. Such children can empty their lungs quickly and may not be able to hold an expiratory plateau for 1 s. Note that complete expiration was attained in less than 2 s, even though the plateau was not held for 1 s. In this patient, the FVC was provisionally acceptable following this maneuver and was judged to be acceptable when it was found to be within 0.100 L of the FVC from subsequent maneuvers.

Within-Maneuver "Acceptability"
Obstructed mouthpiece or spirometer

- **Must have no evidence of obstructed mouthpiece or spirometer**
  - Yes, required for Acceptability for both FEV1 & FVC
  - No, not required for Usability for both FEV1 & FVC

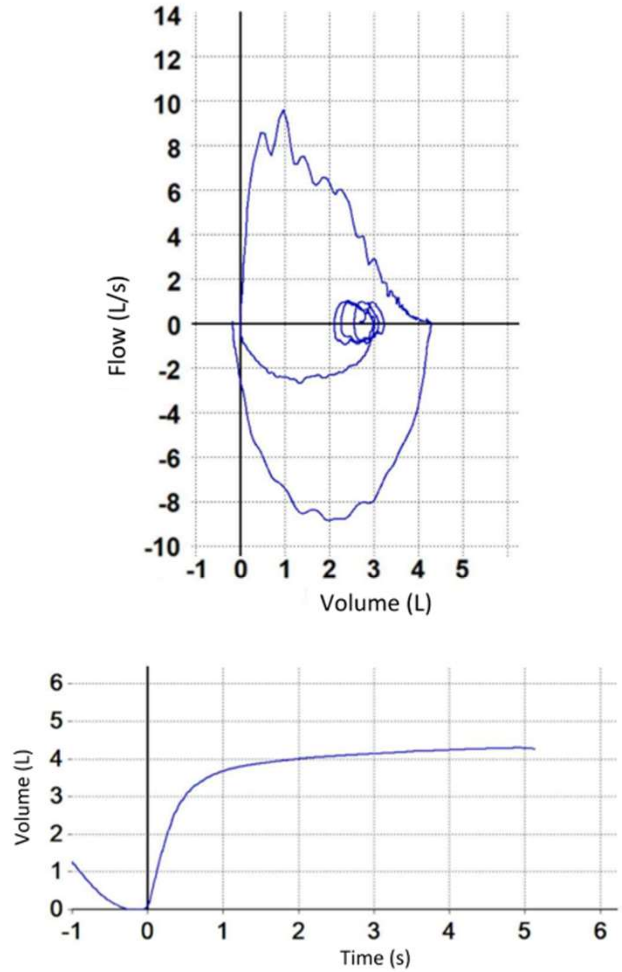


Figure E12. When the tongue obstructs the mouthpiece, there is a reduced flow and often a flutter can be seen in the flow-volume curve. The flow oscillations (sometimes referred to as sawtoothing) seen in this flow-volume curve may also be seen in cases of upper or central airway obstruction. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

Within-Maneuver “Acceptability”
Leak

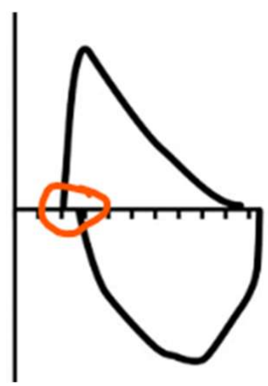
- **Must have no evidence of a leak**
  - Yes, required for <u>Acceptability</u> for both FEV1 & FVC
  - No, not required for <u>Usability</u> for neither FEV1 nor FVC
- flange-type mouthpiece
  - or assistance from the operator

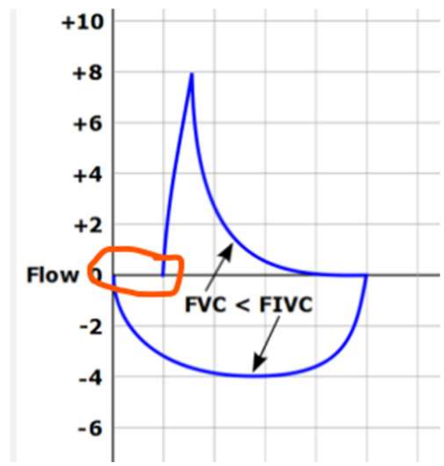
4 Maximums: Within-Maneuver "Acceptability" Max #4) FIVC

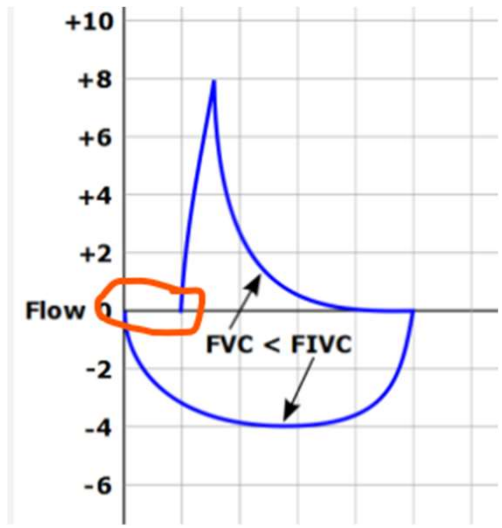
- Returning from
  - EOFE
  - FVC
  - Maximum expiration level
- Returning to
  - Maximum inspiration level
  - TLC
- Maximum Volume

4 Maximums: Within-Maneuver "Acceptability"
Max #4) FIVC

- **If the maximal inspiration after EOFE is greater than FVC, then FIVC – FVC must be ≤0.100 L or 5% of FVC, whichever is greater‡**
  - Yes, required for Acceptability for both FEV1 & FVC
  - No, not required for Usability for neither FEV1 nor FVC
- ‡Although the performance of a maximal forced inspiration is strongly recommended, its absence does not preclude a maneuver from being judged acceptable, unless extrathoracic obstruction is specifically being investigated.






+10
+8
+6
+4
+2
Flow 0
-2
-4
-6
FVC < FIVC

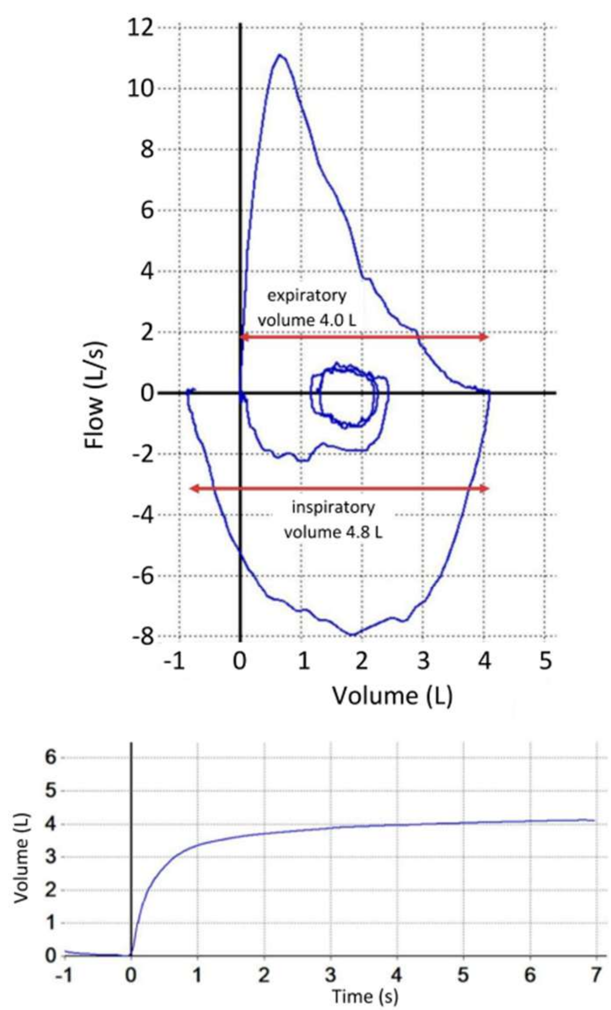
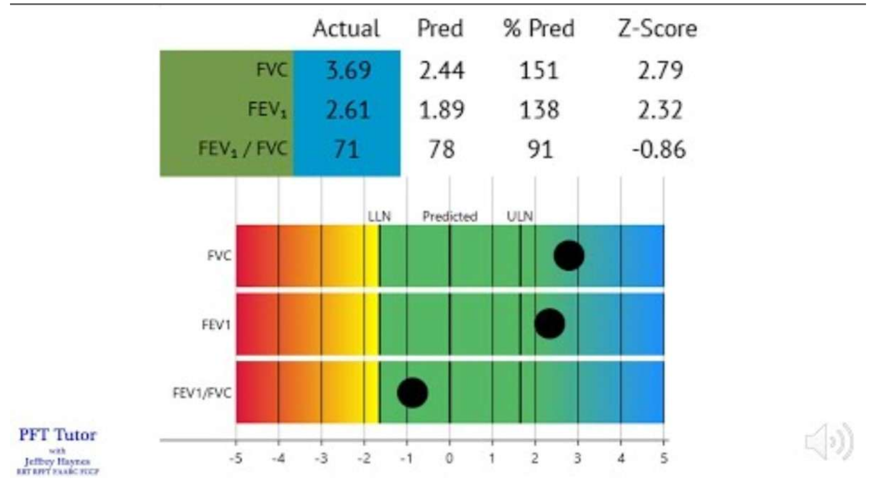


Figure E10. When the inspiratory volume at the end of the maneuver exceeds the forced expiratory volume, the subject did not reach total lung capacity before blowing out. The maneuver is not acceptable if the inspiratory volume exceeds the FVC by more than 0.100 L or 5% of FVC, whichever is greater. In this example, neither FEV_1 nor FVC is acceptable. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

[PFT Tutor with Jeffrey Haynes: What Should You Do When PFT Values Appear Too Good To Be True?](#) (10:45)



Key Points

- Be suspicious whenever PFT values are higher than expected
- Demographic errors may create erroneous z-scores
- Technical errors should be ruled out
  - BTPS factor/temperature measurement
  - Positive zero flow error
  - Flow sensing device malfunction
- Verify functionality with calibration verification and BioQC
- Sometimes high values are physiologic
- Document that data accuracy was verified

Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

2. explain **4 Maximums** within the forced vital capacity maneuver
    - as part of the spirometry **procedure**
    - as within-maneuver criteria for "**acceptability**" and "**usability**"
    - as between-maneuver criteria for "**repeatability**"

Between-Maneuver Repeatability – Applied to “Acceptable “ FEV1 & FVC

(Old Term: Reproducibility)

Adults and Children age > 6 y.o.

- The difference between the two largest **FVC** values must be ≤ **0.150 L** and
- The difference between the two largest **FEV1** values must be ≤ **0.150 L**

Children ≤ 6 y.o.

- The difference between the two largest **FVC** values must be ≤ **0.100 L** or 10% of the highest value, whichever is greater, and
- The difference between the two largest **FEV1** values must be ≤ **0.100 L** or 10% of the highest value, whichever is greater

Application of Acceptability and Repeatability Criteria

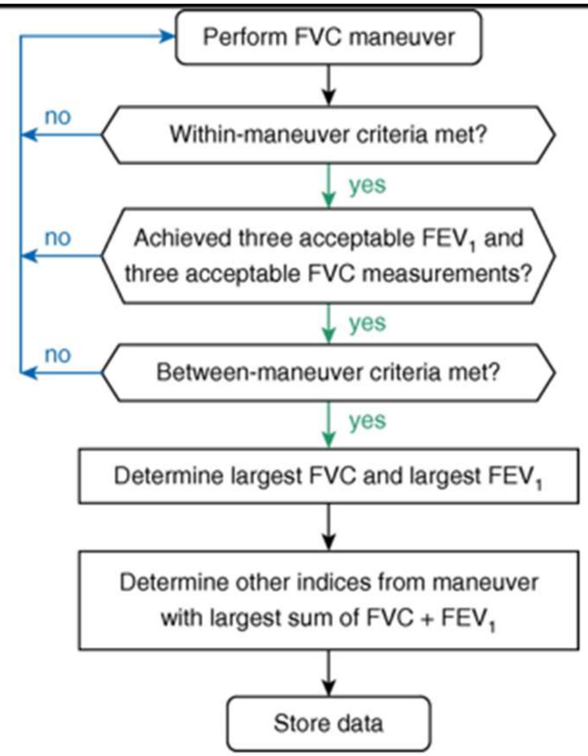


Figure 3. Flowchart outlining application of acceptability and repeatability criteria.

Am J Respir Crit Care Med, 2019

Learning Objectives

At the conclusion of this presentation
the learner shall be able to…

2. explain **4 Maximums** within the forced vital capacity maneuver
    - as part of the spirometry **procedure**
    - as within-maneuver criteria for "**acceptability"** and "**usability"**
    - as between-maneuver criteria for "**repeatability"**
    - as session quality **grading**

Grading System for FEV1 & FVC

- Table 10. Grading System for FEV1 and FVC (Graded Separately)

- 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 FEV1 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.

Post Test Comments

Double-click on the row header to insert comment.
Double-click in a cell to edit.

ID	Description
1	Good patient effort.
1.1	Moderate patient effort.
1.2	Fair patient effort.
1.3	Poor patient effort.
2	Patient was able to meet ATS/ERS criteria for usability/repeatability.
2.1	Patient was unable to meet ATS/ERS criteria for usability/repeatability for spirometry; best effort was reported.
2.2	Patient was unable to meet ATS/ERS criteria for usability/repeatability for DLCO; best effort was reported.
2.3	Patient was unable to meet ATS/ERS criteria for usability/repeatability for lung volumes; best effort was reported.
2.4	Patient was unable to meet ATS/ERS IVC > 90% criteria for DLCO; values may be underestimated.
2.5	The patient was unable to perform maneuvers necessary for testing despite coaching and demonstration.
2.7	The patient was unable to perform DLCO or lung volumes due to desaturation off supplemental oxygen.
2.8	The patient was unable to comprehend the instructions necessary for testing coaching and demonstration.
2.9	Data obtained and manually entered from other spirometer. Test performed by
3.0	No current hemoglobin available for DLCO correction.
3.1	DLCO corrected for a hemoglobin of gm/dL dated.
3.3	Inhaler last used:
3.4	Procedural instructions given through an interpreter.
4.0	Post-bronchodilator testing performed after the patient received a treatment with 2.5 mg albuterol via nebulizer.
4.1	Post-bronchodilator testing performed after the patient received a treatment of 0.63 mg levalbuterol via nebulizer.

Learning Objectives

At the conclusion of this presentation the learner shall be able to…

1. describe the basics of **spirometry context**
2. explain **4 Maximums** within the forced vital capacity maneuver
3. explain **troubleshooting and coaching** to correct spirometry errors and meet ATS/ERS criteria

System Warnings: Coach to Correct to ATS/ERS

Warning trigger	Warning message	Instruction to patient
BEV exceeds limit	hesitant start	blast out immediately when completely full
rise time > 150 ms*	slow start	blast out immediately when completely full
no plateau and expiration < 15 s	no plateau	keep going until completely empty
hesitation time > 2 s	hesitation at maximum volume	blast out when completely full
FVC less than max FVC from previous maneuvers	low forced expiratory volume	take the deepest breath possible and keep going until completely empty
FIVC > FVC	incomplete inspiration prior to FVC	fill your lungs completely before blasting out – take the deepest breath possible
FIVC < 90%FVC	low final inspiration	after completely emptying your lungs, remember to breathe in - back to the top
mean inspiratory flow of the breath just prior to forced expiration is less than 2 L/s	slow filling	breathe in faster before blasting out
suspected glottis closure†	abrupt stop	if you feel your throat closing, relax, but keep pushing
suspected cough in first second of expiration‡	cough in first second of expiration	try having a sip of water before the next blow

System Warning: “Hesitant Start”

- Warning Trigger:
  - BEV exceeds limit

- Instruction to Patient:
  “Blast out immediately when completely full”

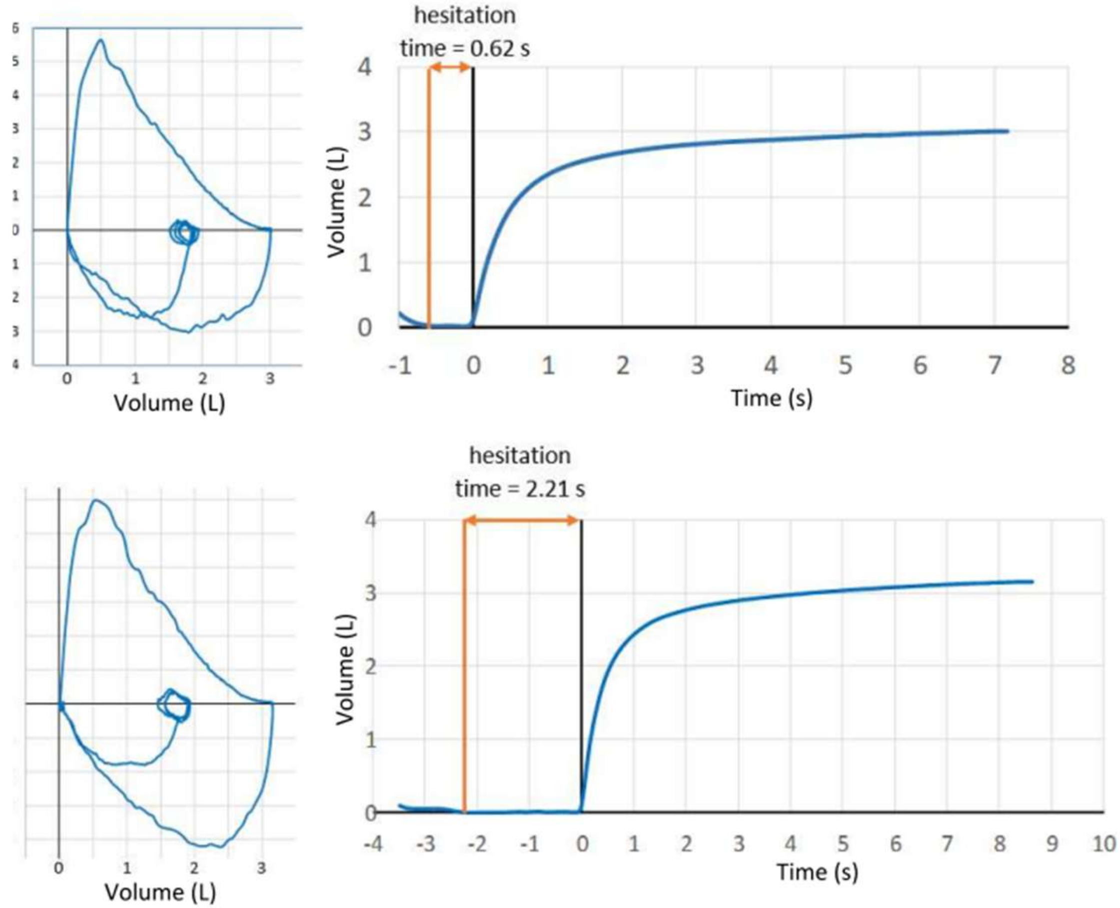
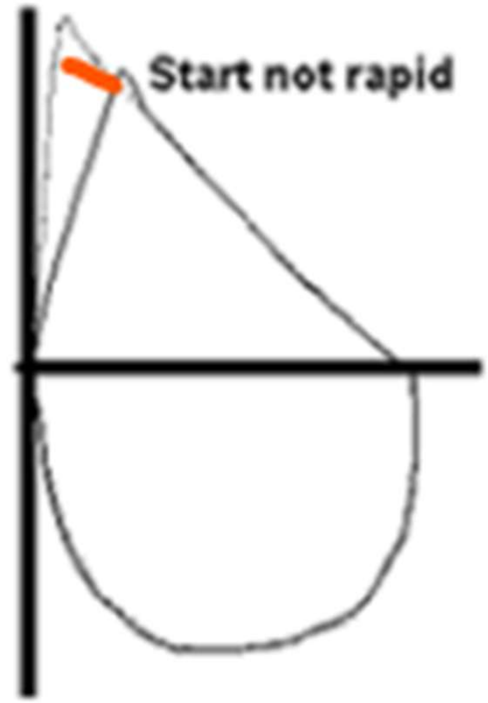


Figure E13. Hesitation time is defined as the time from attaining maximum inspired lung volume to the back-extrapolated time zero which should be less than 2 s. The upper panel shows an acceptable maneuver with a hesitation time of 0.62 s. The lower panel shows a maneuver from the same person but with a hesitation time of 2.21 s which should generate a warning and a message to instruct the patient to blast out immediately when completely full.

System Warning: “Slow Start”

- Warning Trigger:
    - Rise Time > 150 ms
    - Peak shifted to the right

- Instruction to Patient:
  “Blast out immediately when completely full”



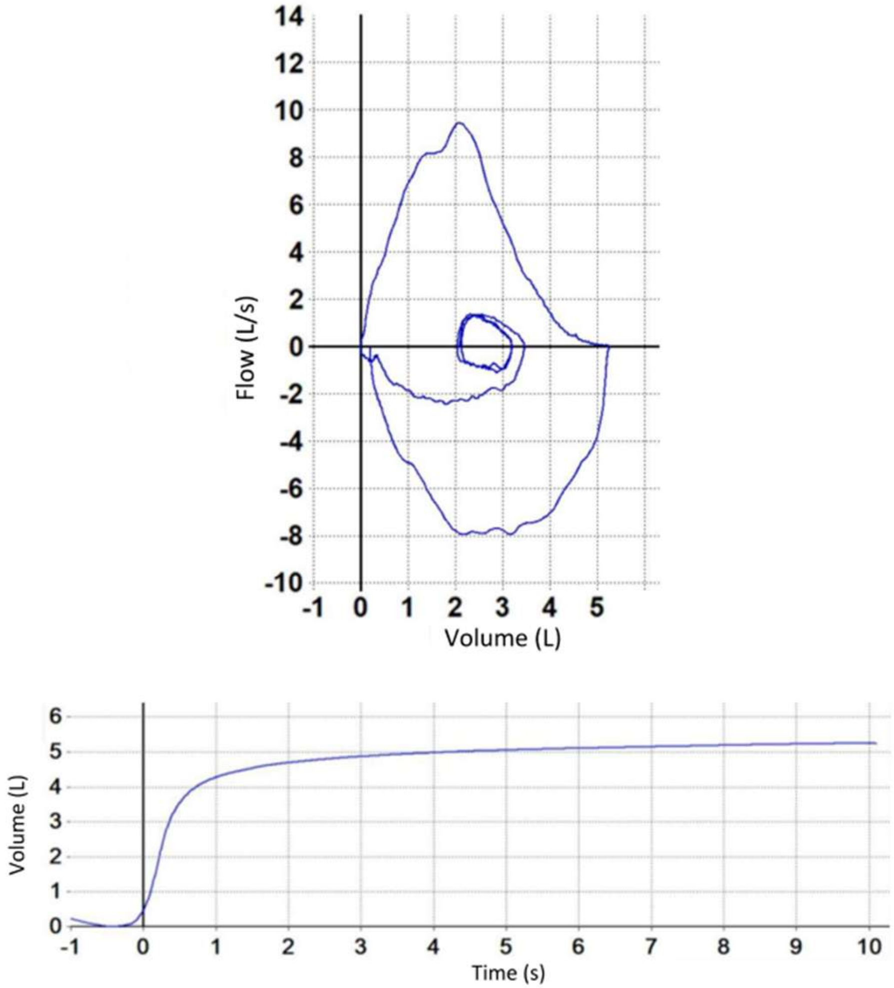


Figure E11. When a subject has a slow start to expiration, the flow-volume curve may still show a peak but it occurs later in expiration. In this example, the rise time from 10% to 90% of peak flow is 320 ms, well in excess the 150 ms recommendation. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

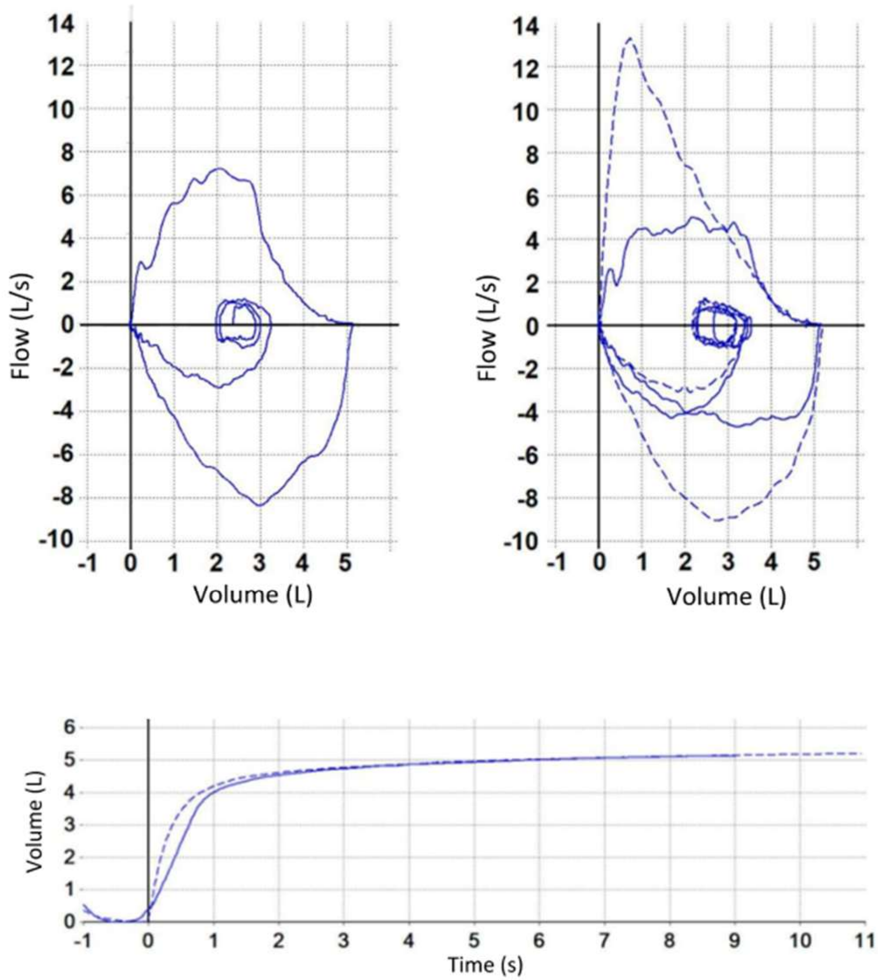
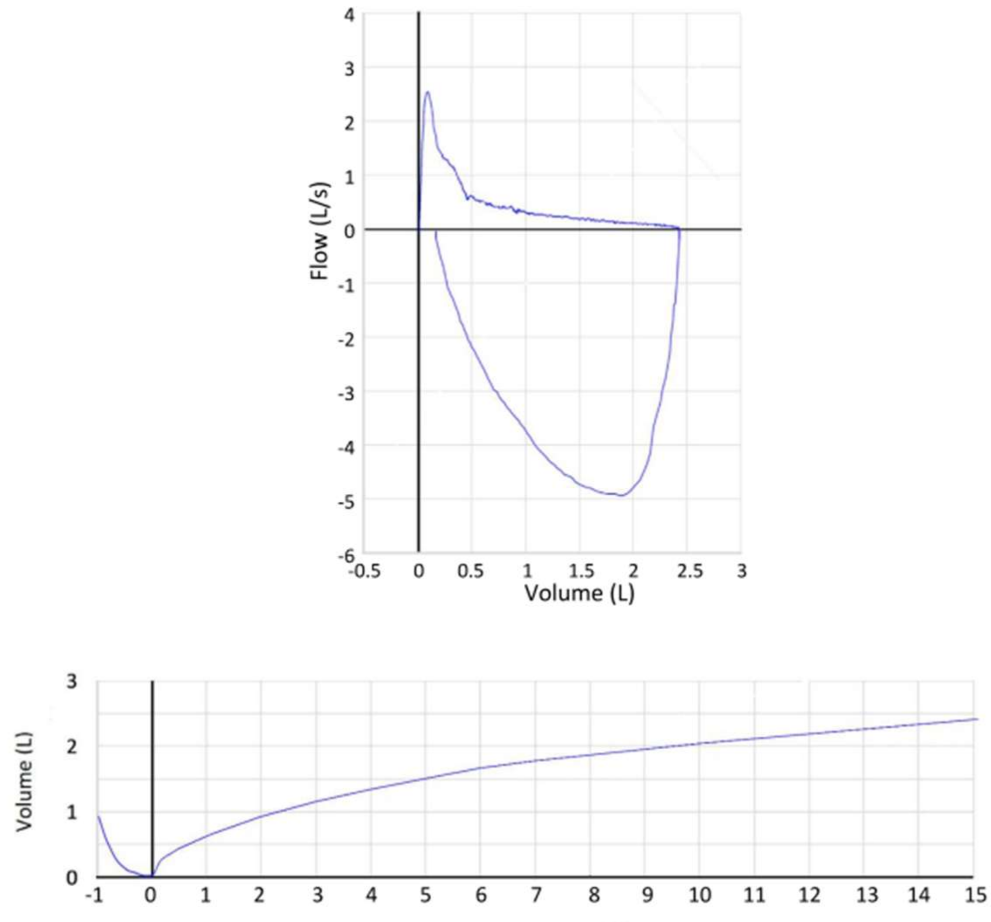


Figure E6. A sub-maximal effort is characterised by a rounded flow-volume curve and a less steep slope at the start of the volume-time curve. Compare a sub-maximal effort (solid line) to an acceptable maneuver (dashed line) in the same subject. A sub-maximal effort will often have a rise time >150 ms which will trigger a warning – see Section E8. *(reproduced with permission – RESPTREC^{TM} Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

System Warning: "No Plateau"

- Warning Trigger:
  - No plateau, and
  - expiration < 15 seconds
- Instruction to Patient:
  - **"Keep going until completely empty"** (and keep them going for the full 15 seconds)



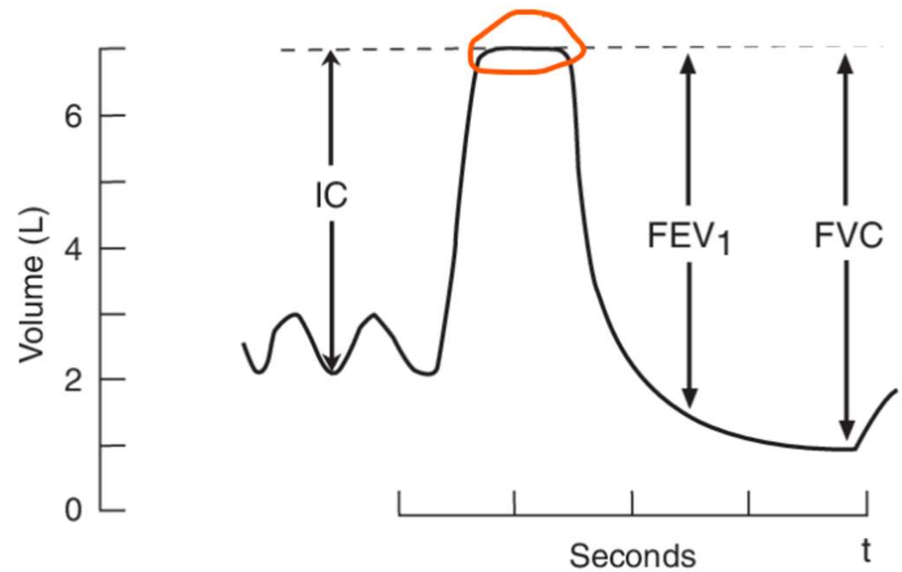
NOTE: This is acceptable because it reached > 15 secs

Figure E3. An acceptable maximal maneuver by a female (age 52.6) yr with very severe obstruction. Note that no plateau was reached by 15 s of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

System Warning:
“Hesitation at Maximum Vol”

- Warning Trigger:
  - Hesitation time > 2 s

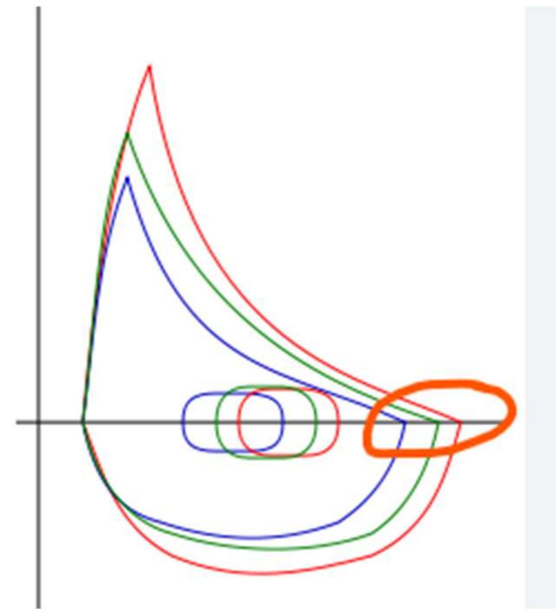
- Instruction to Patient:
  - **“Blast out immediately when completely full”**



System Warning:
“Low Forced Expiratory Volume”

- Warning Trigger:
  - FVC less than max FVC from previous maneuvers

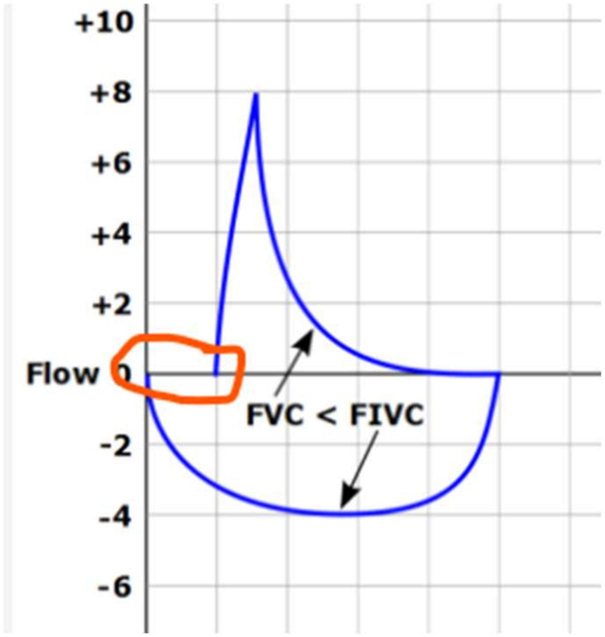
- Instruction to Patient:
  - **“Take the deepest breath possible and keep going until completely empty”**



System Warning:
"Incomplete Inspiration Prior to FVC"

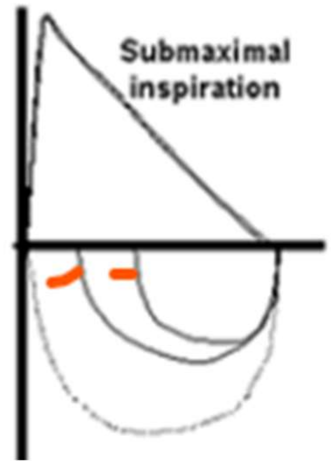
- Warning Trigger:
  - FIVC > FVC

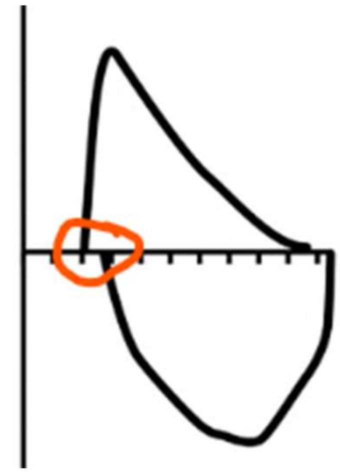
- Instruction to Patient:
  - **"Fill your lungs completely before blasting out – take the deepest breath possible"**



System Warning: “Low Final Inspiration”

- Warning Trigger:
  - FIVC < 95% FVC
- Instruction to Patient:
  - **“After completely emptying your lungs, remember to breathe in – back to the top”**



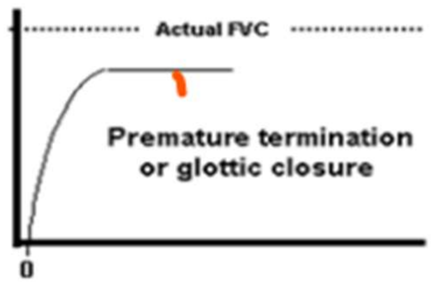


System Warning: “Slow Filling”

- Warning Trigger:
  - Mean inspiratory flow of the breath just prior to forced expiration is less than 2 L/s
- Instruction to Patient:
  - **“Breathe in faster before blasting out”**

System Warning: "Abrupt Stop"

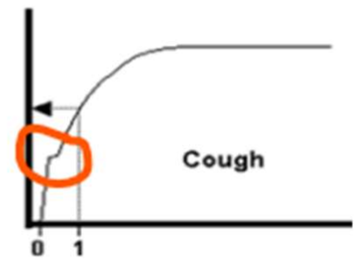
- Warning Trigger:
  - Suspected glottis closure
- Instruction to Patient:
  - **"If you feel your throat closing, relax, but keep pushing"**
  - **"Maintain slight chin elevation"**
  - **Hold the spirometer level to the floor "like a trumpet"**



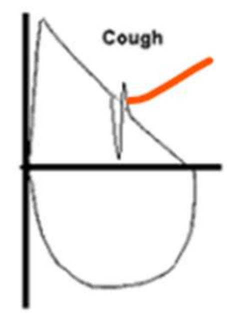
Early termination
Glottic closure

System Warning:
"Cough in First Second of Expiration"

- Warning Trigger:
  - Suspected cough in first second of expiration

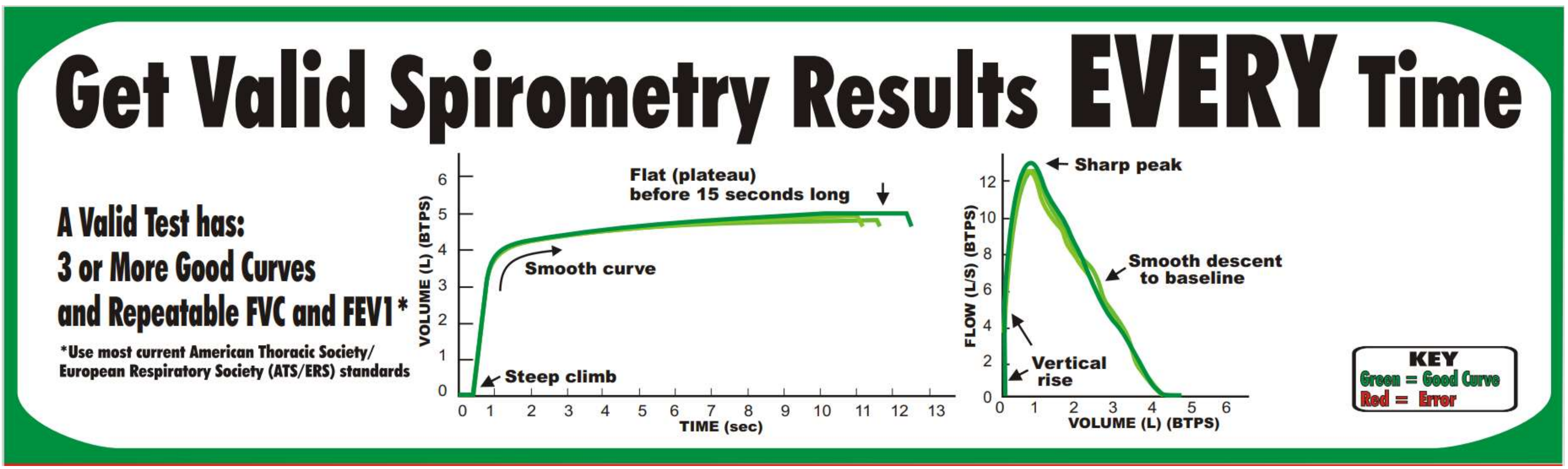


- Instruction to Patient:
  - **"Try having a sip of water before the next blow"**



Get Valid Spirometry Results EVERY Time

CDC - NIOSH: [DHHS (NIOSH) Publication No. 2011-135]



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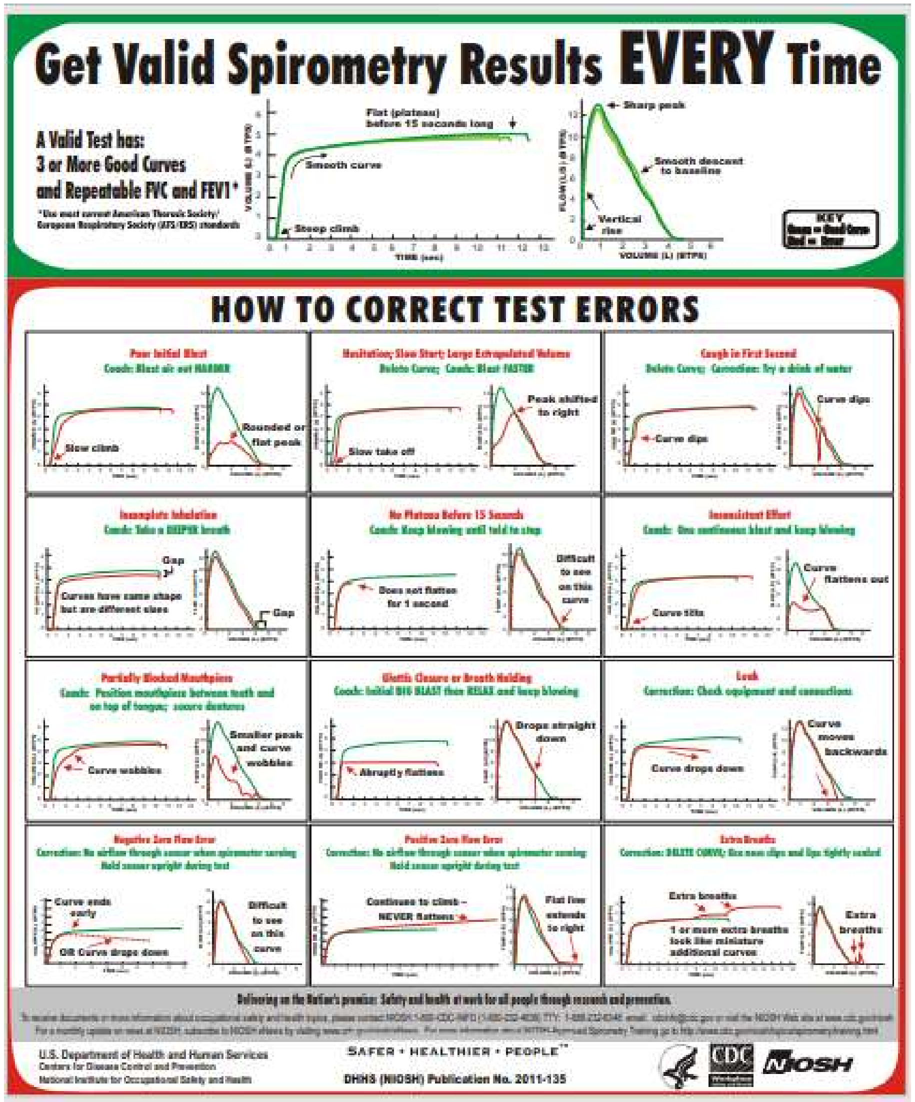

Poor Performance?

ASK the patient….

- Do make sure that the poor performance is not:
  - due to pain
  - due to stress incontinence
  - not understanding

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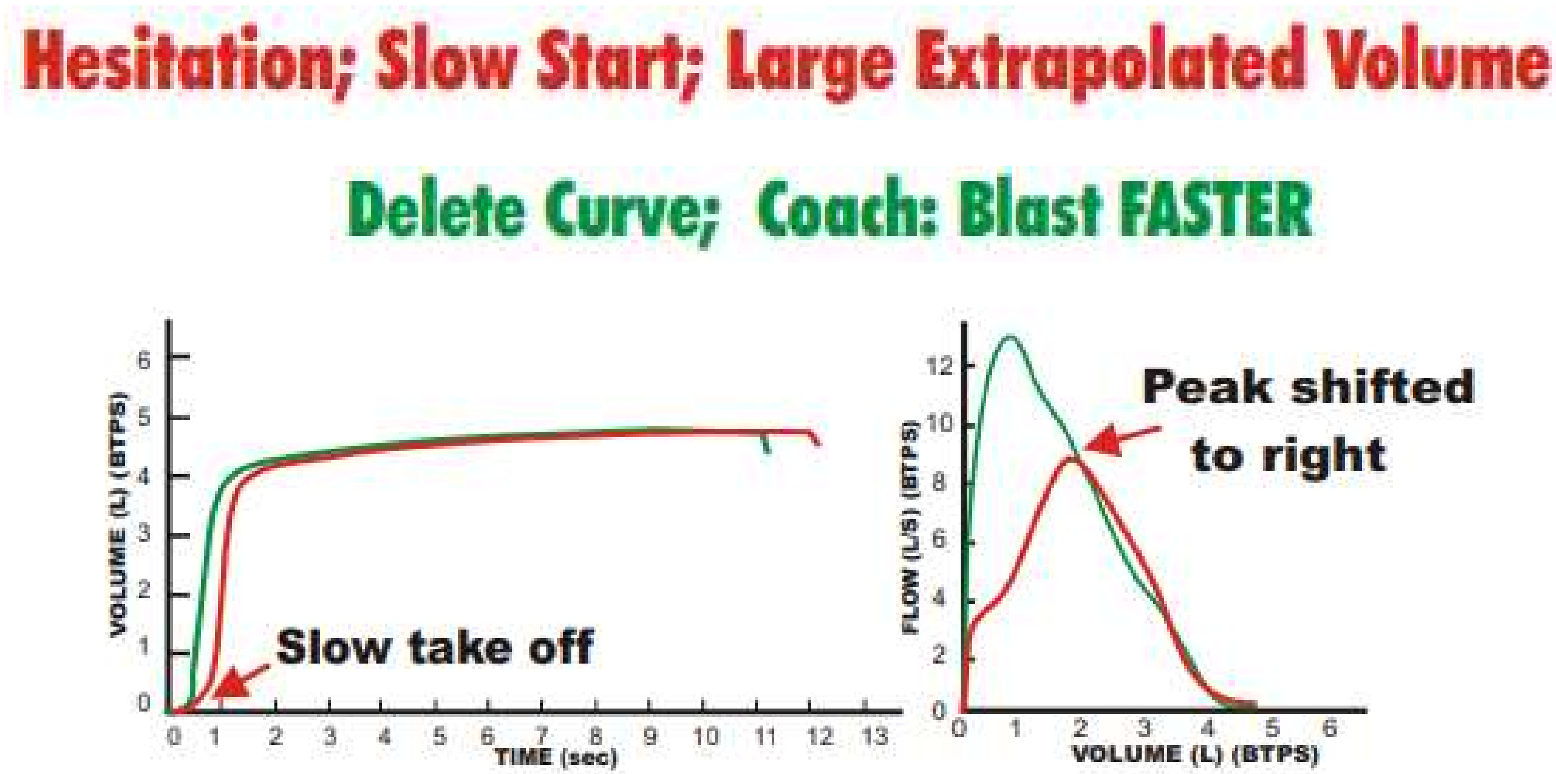
Get Valid Spirometry Results EVERY Time



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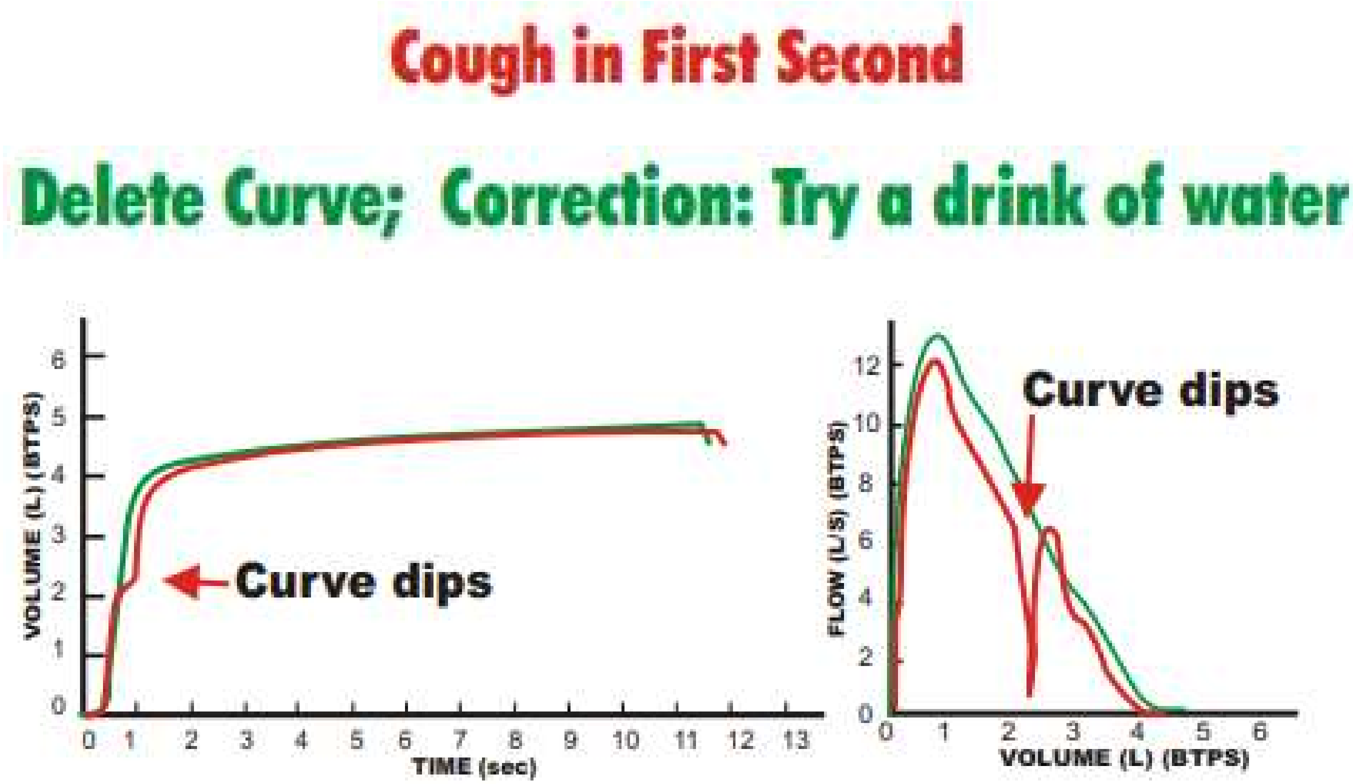

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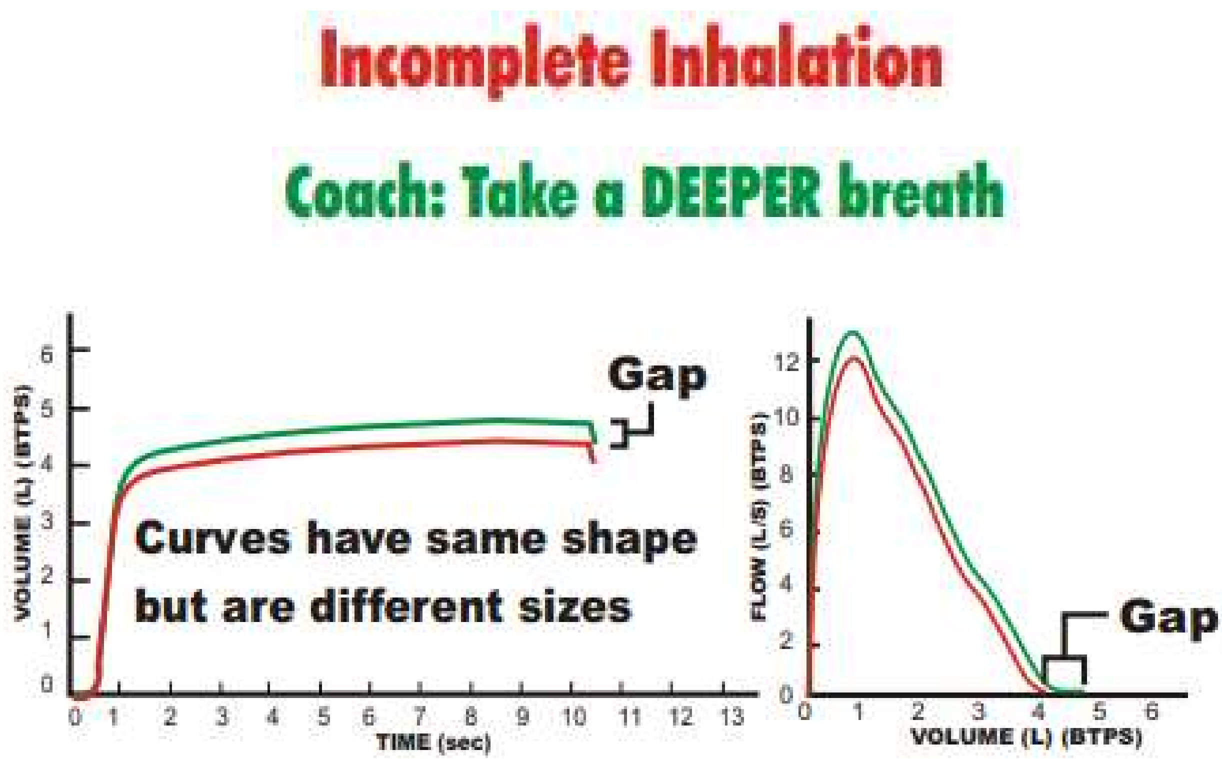

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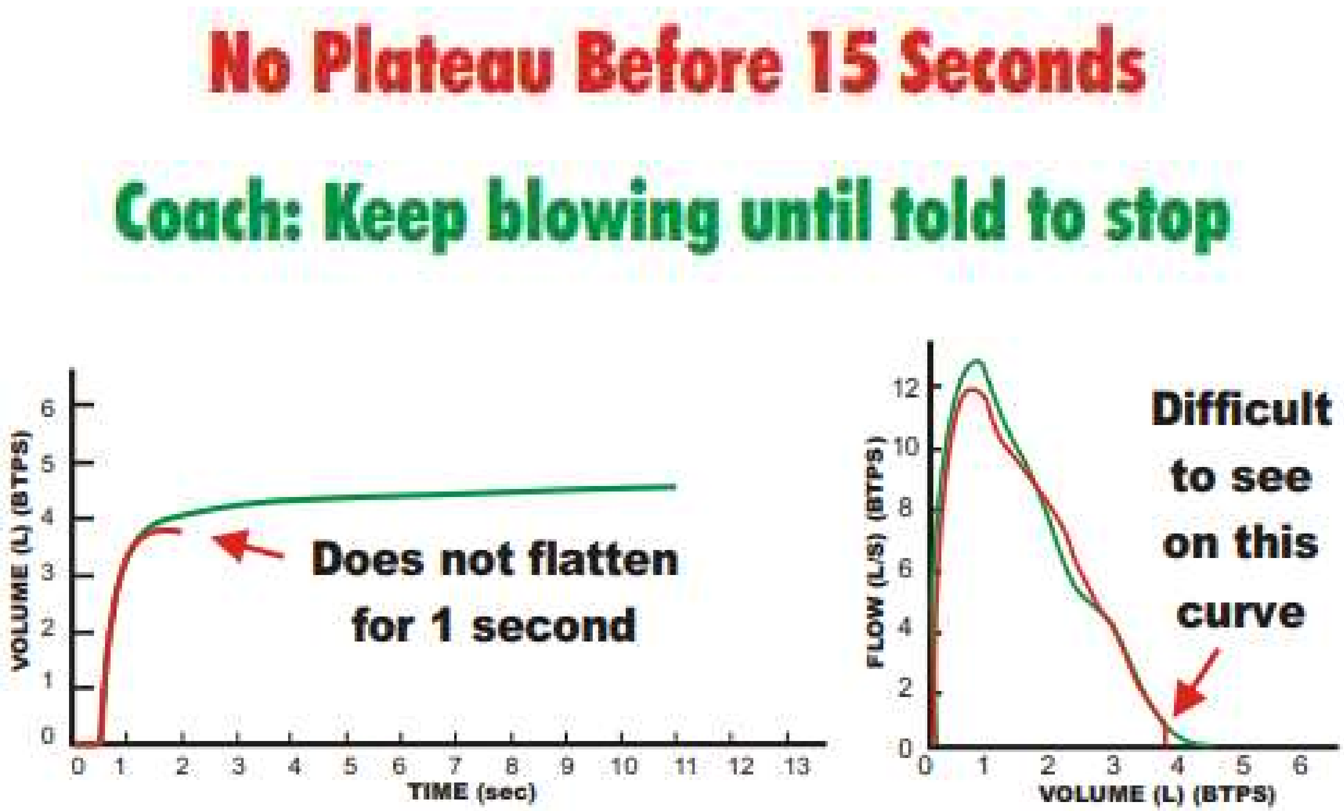

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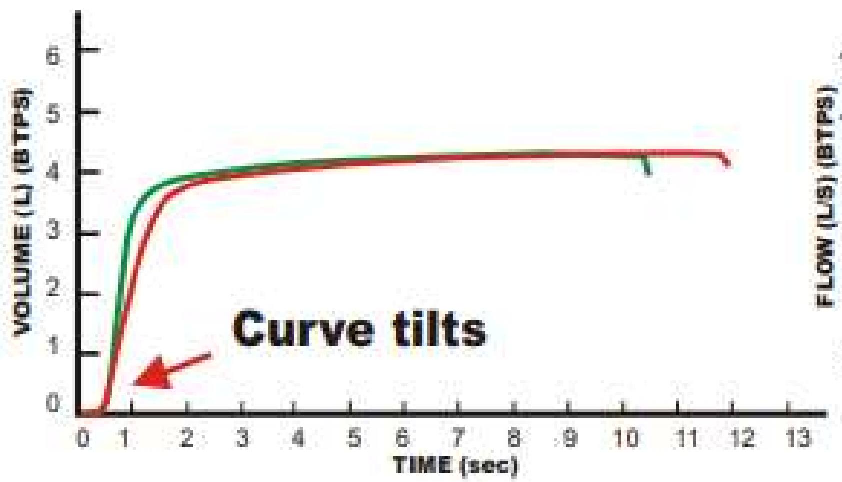
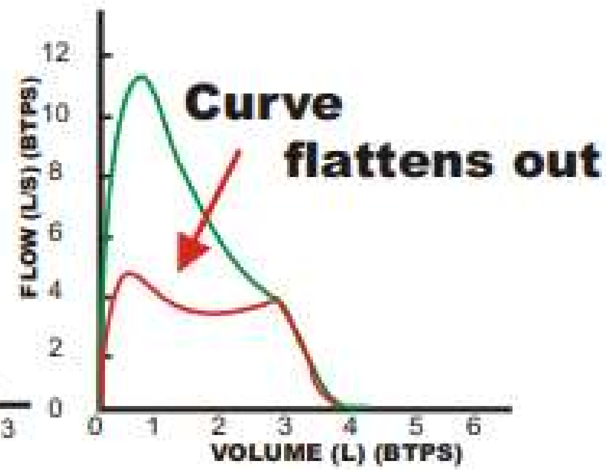
Inconsistent Effort

Coach: One continuous blast and keep blowing





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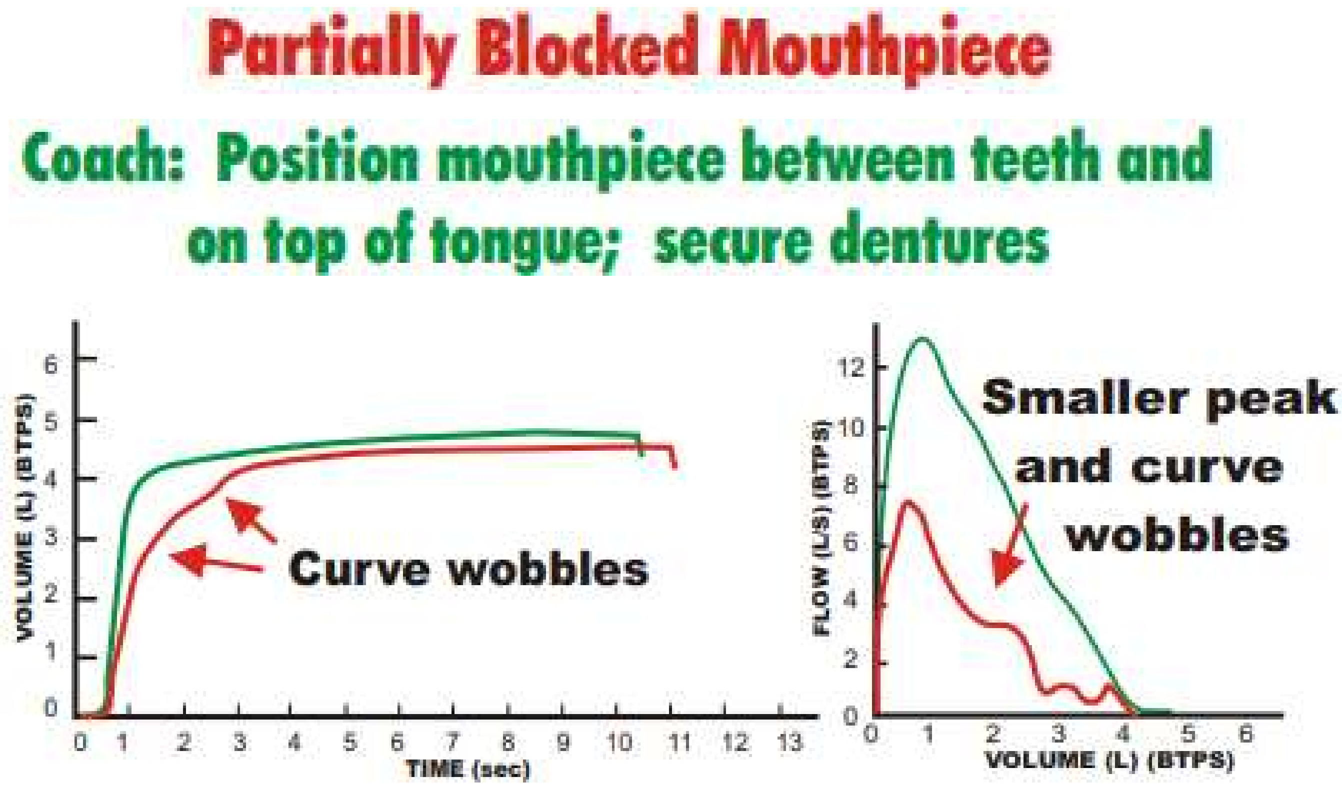

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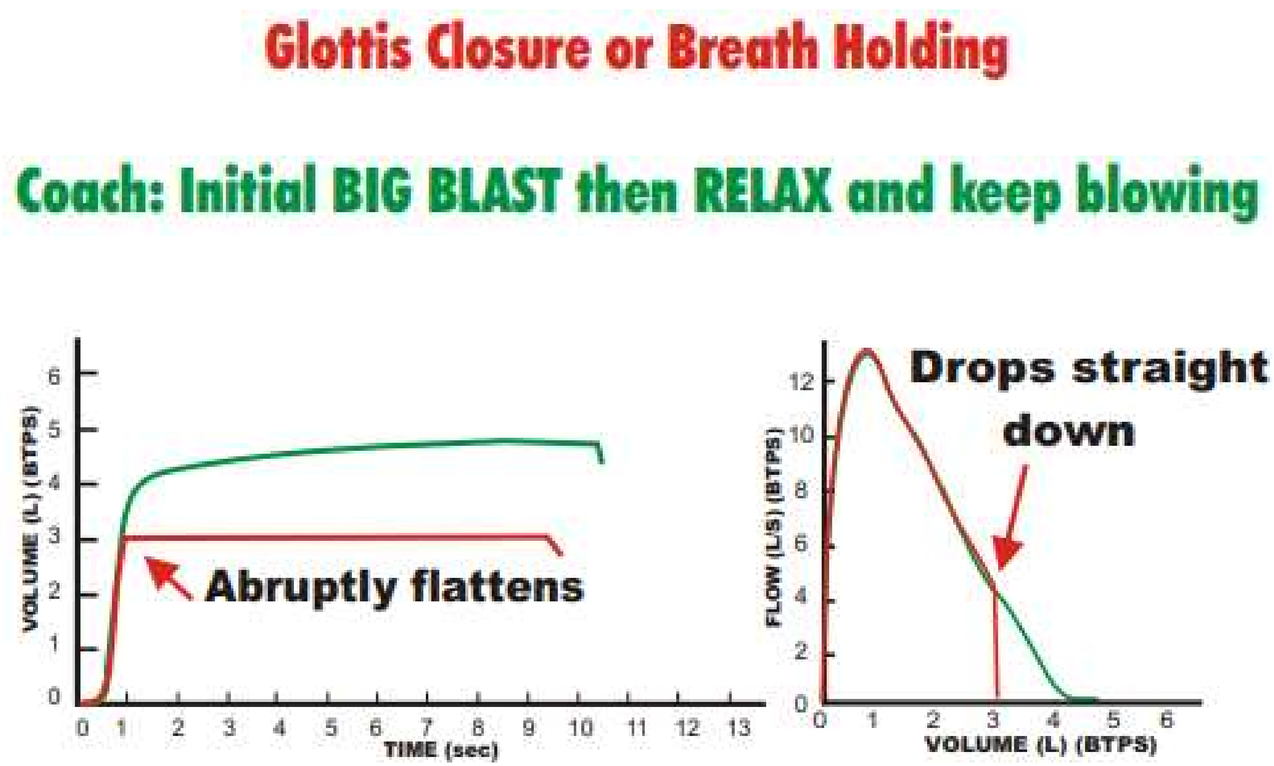
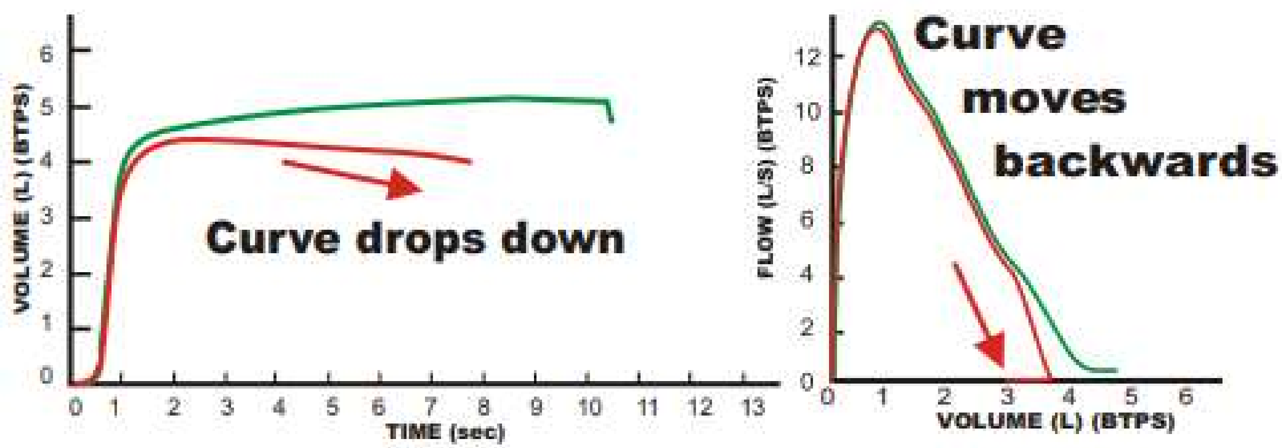


Get Valid Spirometry Results EVERY Time

Leak

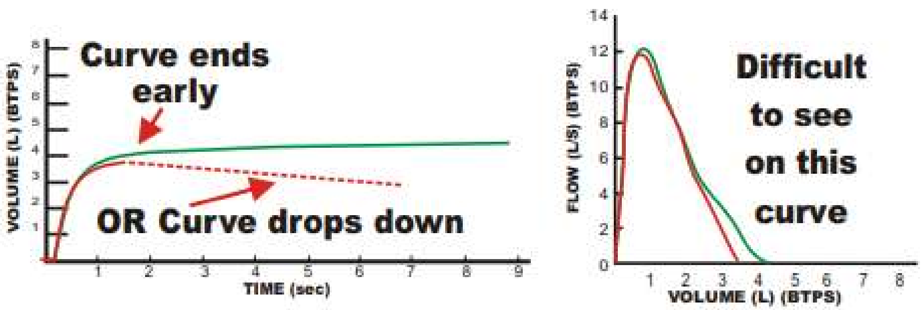
Correction: Check equipment and connections

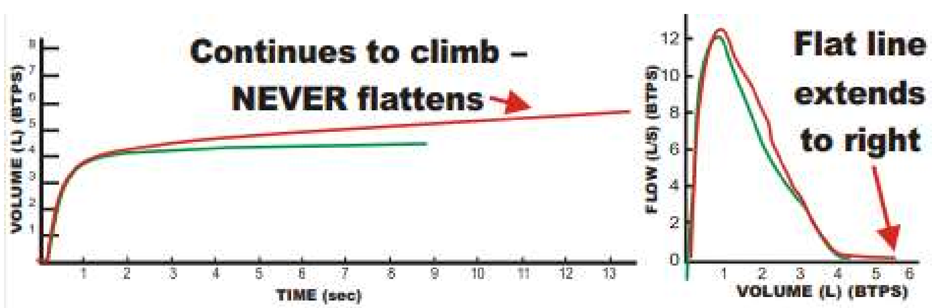


Get Valid Spirometry Results EVERY Time

Negative Zero Flow Error **Positive Zero Flow Error**

Correction: No airflow through sensor when spirometer zeroing
Hold sensor upright during test





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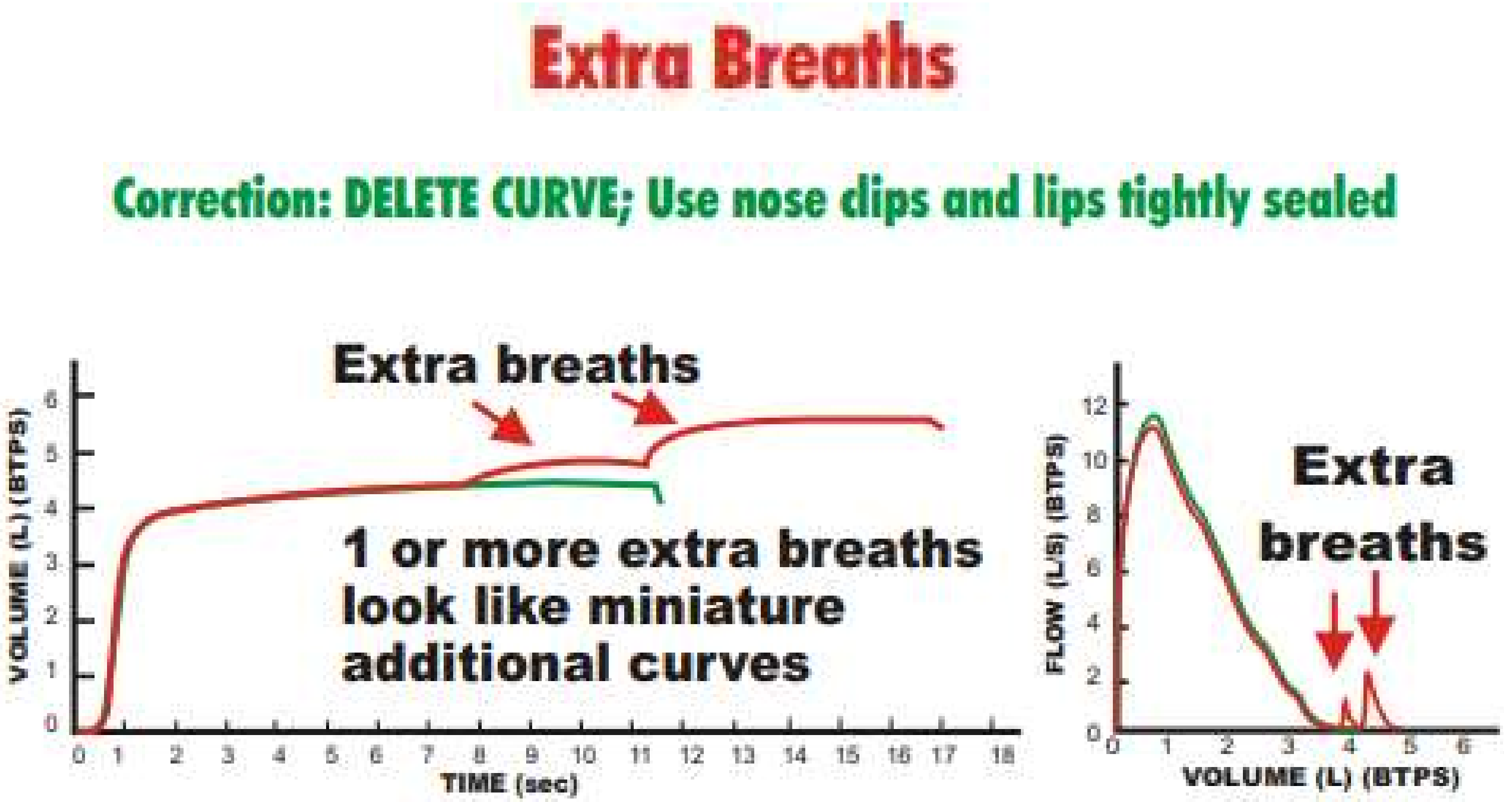
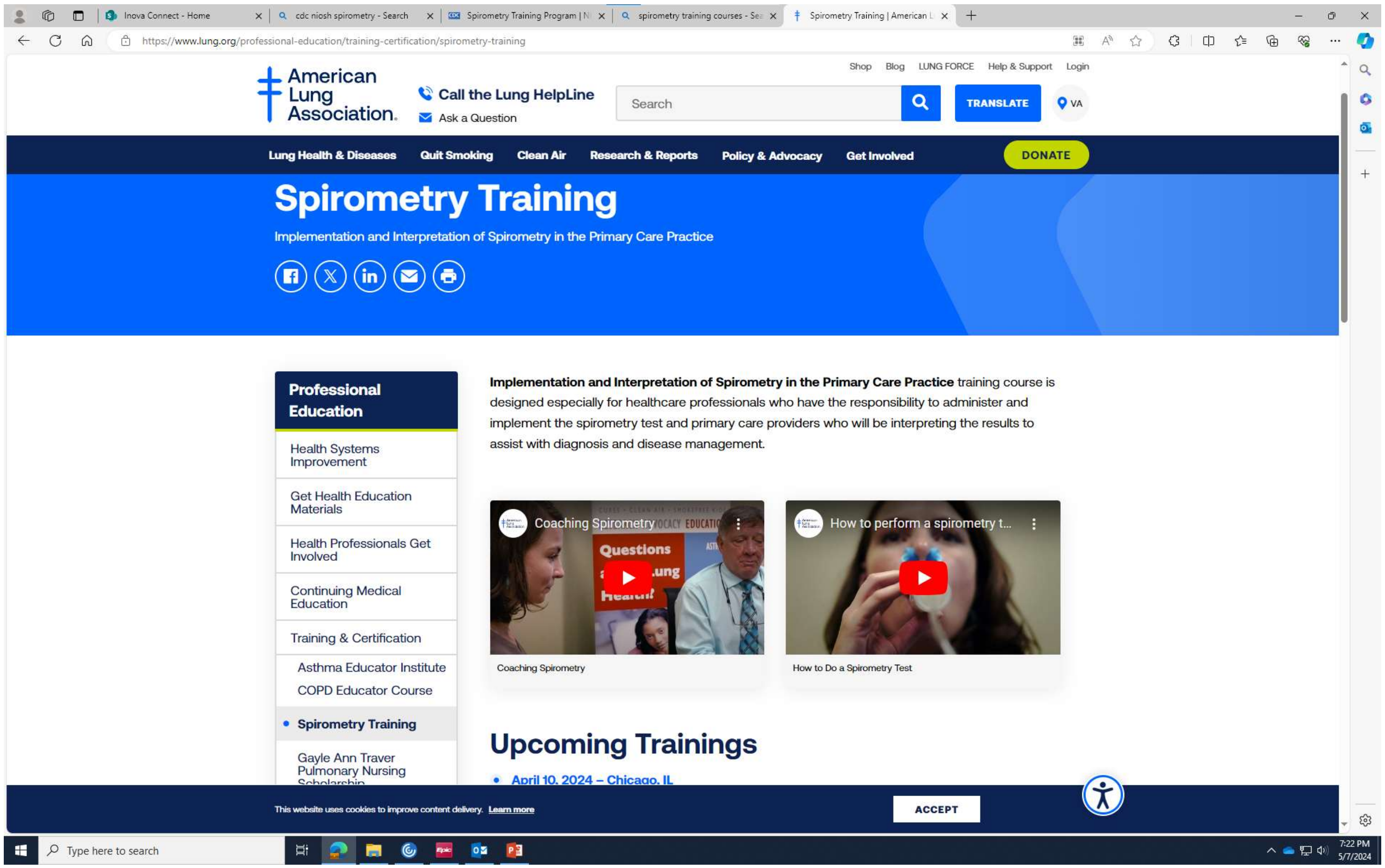


American Lung Association Spirometry



AARC Spirometry Course

Pulmonary Function Technology- Spirometry

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About This Course

This spirometry course will discuss obstructive and restrictive disease processes, basic measurements, reference values, repeatability and acceptability, and how to perform a quality procedure. Also discussed is calibration of the spirometer and patterns of abnormal results.

Participants should read the ATS/ERS Task Force Standardisation of Lung Function Testing: Standardization of Spirometry guideline, the GOLD Spirometry Guide, and the GOLD Spirometry Quick Guide (included for convenience).

Successful completion of this course includes earning a score of 70% or higher on the course post-test.

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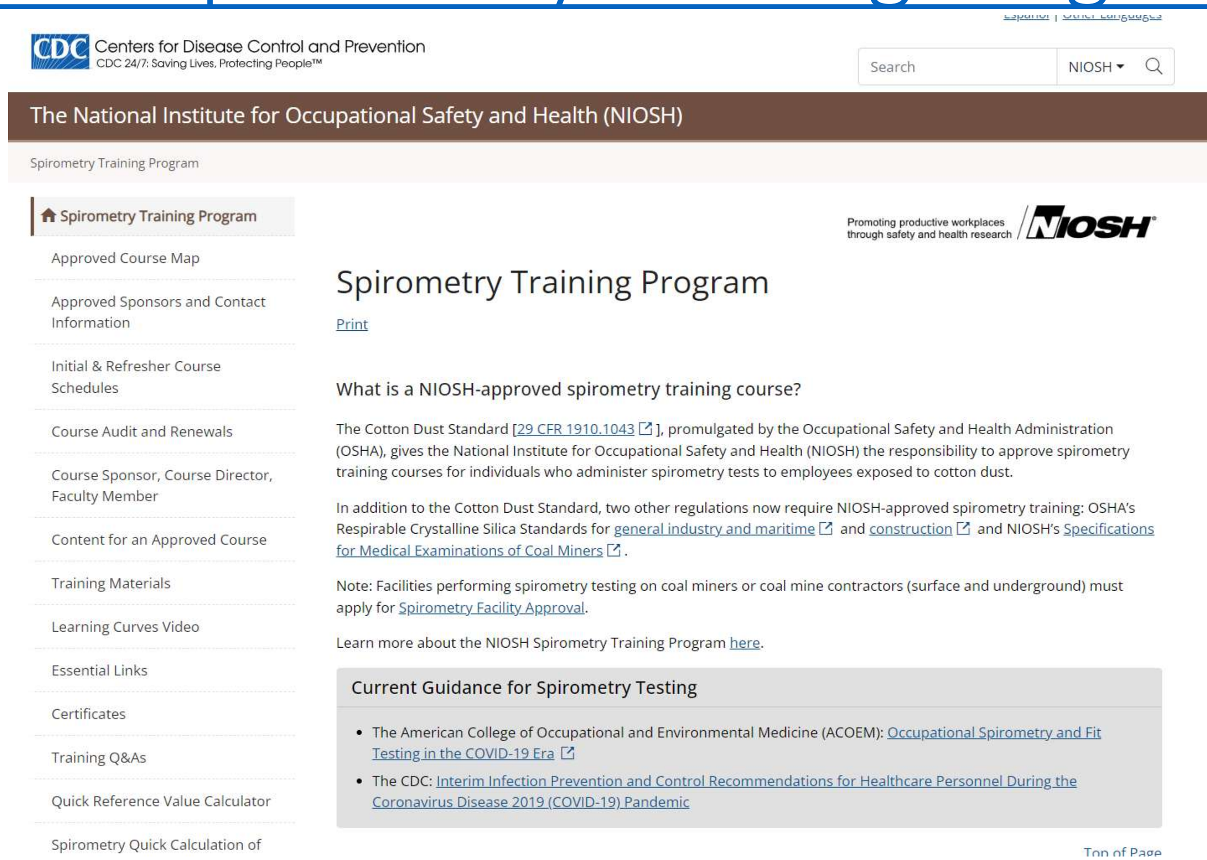
CDC NIOSH Spirometry Training Program



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The National Institute for Occupational Safety and Health (NIOSH)

Spirometry Training Program

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Spirometry Training Program

Print

What is a NIOSH-approved spirometry training course?

The Cotton Dust Standard [29 CFR 1910.1043], promulgated by the Occupational Safety and Health Administration (OSHA), gives the National Institute for Occupational Safety and Health (NIOSH) the responsibility to approve spirometry training courses for individuals who administer spirometry tests to employees exposed to cotton dust.

In addition to the Cotton Dust Standard, two other regulations now require NIOSH-approved spirometry training: OSHA's Respirable Crystalline Silica Standards for general industry and maritime and construction and NIOSH's Specifications for Medical Examinations of Coal Miners.

Note: Facilities performing spirometry testing on coal miners or coal mine contractors (surface and underground) must apply for Spirometry Facility Approval.

Learn more about the NIOSH Spirometry Training Program here.

Current Guidance for Spirometry Testing

- The American College of Occupational and Environmental Medicine (ACOEM): Occupational Spirometry and Fit Testing in the COVID-19 Era
- The CDC: Interim Infection Prevention and Control Recommendations for Healthcare Personnel During the Coronavirus Disease 2019 (COVID-19) Pandemic

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Thank You

- Any Questions?

- Vicki.Rosette@gmail.com