Deep Breath IN…

Coaching bedside spirometry

to meet ATS/ERS criteria for acceptability, usability, and repeatability

AARC Approved for 1 CRCE Credit Hour

Speaker

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Pulmonary Diagnostics

Disclaimer / Conflict of Interest

- None

Learning Objectives

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

- describe the basics of **spirometry context**
  - Definitions, 4 volumes, 4 capacities, 4 levels, history, indications, contraindications, calibrations, infection control, & operator factors
- **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
- **explain troubleshooting and coaching** to correct spirometry errors and meet ATS/ERS criteria

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Definitions

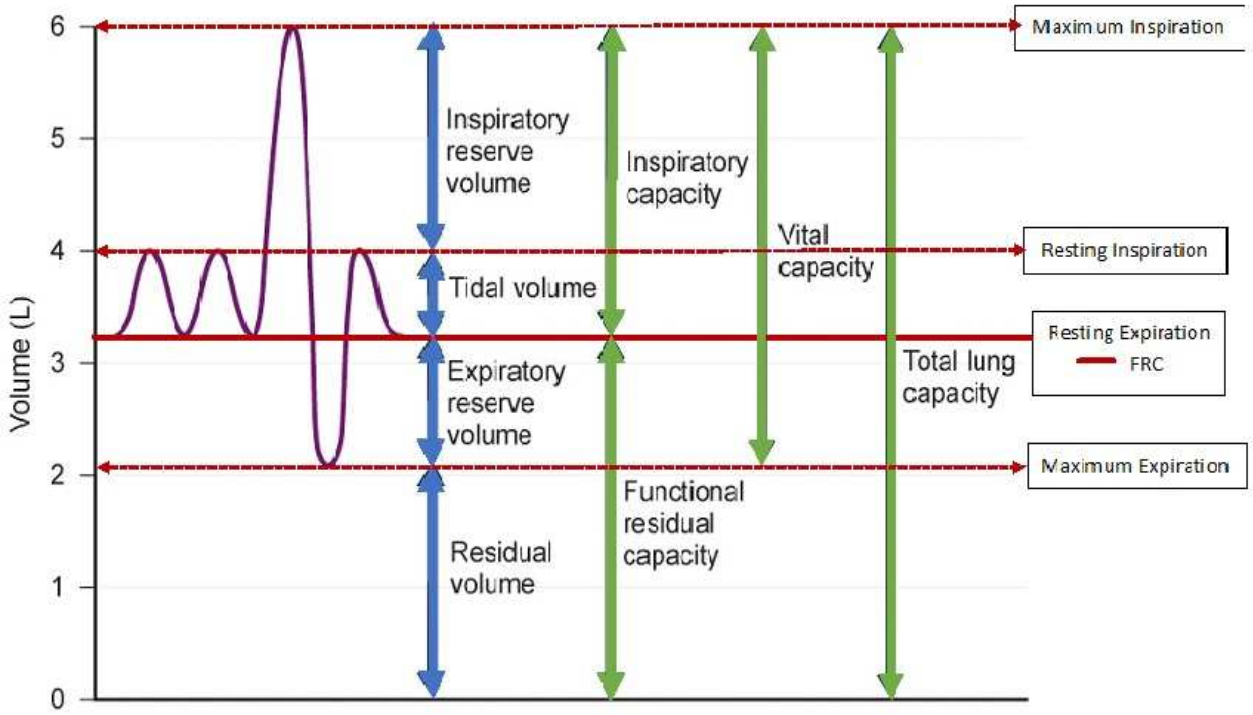
- **Spirometry** is a physiological test that measures the maximal volume of air that an individual can inspire and expire with maximal effort.

- The most relevant measurements:
  - **FEV_1**: the **F**orced **E**xpiratory **V**olume in the first second of an 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?

Acronyms & More Definitions

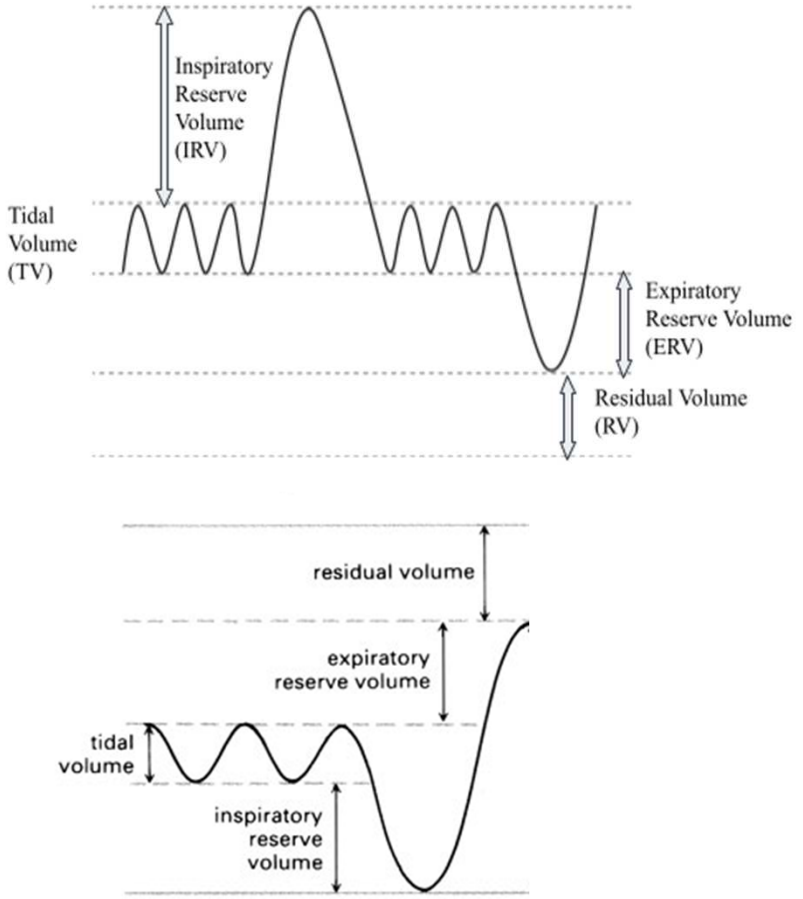
- ATS is the American Thoracic Society
- ERS is the European Respiratory Society
- “Operator” is the person conducting the test
- “Patient” is the person being tested
- “Maneuver” is the term used for the inspiratory and expiratory VC excursions.
- “Must” is used to indicate a requirement
- “Should”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

4 Volumes, 4 Capacities, 4 Levels



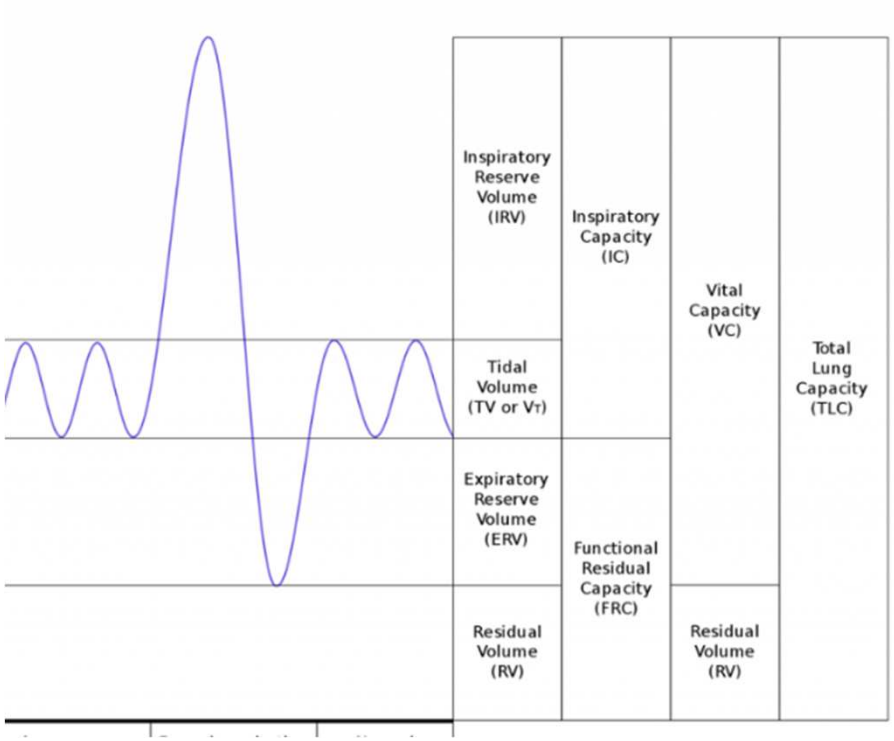
Four Volumes

- **TV or V_T** - **Tidal Volume** is the volume of gas inspired, or expired, during each respiratory cycle at rest
- **IRV** – **Inspiratory Reserve Volume** is the largest volume of gas that can be inspired above the tidal volume
- **ERV** – **Expiratory Reserve Volume** is the largest volume of gas that can be expired from the resting end-expiratory level
- **RV** – **Residual Volume** is the amount of air remaining in the lungs after a forced exhalation



Four Capacities *(Capacity is two or more volumes)*

- **IC – Inspiratory Capacity**
  - TV + IRV
  - VC – ERV
  - TLC - FRC
- **FRC – Functional Residual Capacity**
  - RV + ERV
  - TLC - IC
- **VC – Vital Capacity**
  - TV + IRV + ERV
  - IC + ERV
  - TLC - RV
- **TLC – Total Lung Capacity**
  - TV + IRV + ERV + RV
  - RV + VC
  - IC + FRC



Standardization of Spirometry – American Thoracic Society (ATS) and European Respiratory Society (ERS)

- 2019 Update. Official ATS ERS Technical Statement
  - https://www.atsjournals.org/doi/full/10.1164/rccm.201908-1590ST
- 2005 SERIES ‘‘ATS/ERS Task Force: Standardisation of Spirometry
- 1994 ATS Standardization of Spirometry Update
- 1987 Standardization of Spirometry —Update
- 1979 Snowbird Workshop on Standardization of Spirometry

History of Spirometry Standardization

- 1979 **Snowbird** – *1st standards proposed for clinical & epidemiologic spirometry studies*
- 1987 **Gold Standard** - *against which equipment performance and test performance can be optimized.*
- 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*
- 2005 **Standardisation** of spirometry *ATS & ERS making the user responsible for ensuring that the equipment measurements remain accurate.*
- 2019 ATS & ERS Update and Technical Statement

PFT History

- Courtesy of PFT Forum - The diverse, quirky and mostly forgotten history of Pulmonary Function testing
  - https://www.pftforum.com/history/

Key updates (2005 to 2019) (1 of 2)

- A new list of relative contraindications was added
- Spirometers are now required to meet International Organization for Standardization (ISO) 26782 standards, but with a maximum permissible accuracy error of ±2.5%.
- Device quality assurance procedures were updated.
- Operator training as well as attainment and maintenance of competency were addressed.
- The list of activities that patients should avoid before testing was updated.
- There is a focus on the use of devices that measure both expiration and inspiration

Key updates (2005 to 2019) (2 of 2)

- Maneuver acceptability and repeatability criteria were updated. The end of forced expiration (EOFE) was redefined.
- Requirements for spirometry systems to provide uniform cues and feedback to the operator were added.
- New withholding times for bronchodilators before bronchodilator responsiveness testing were developed.
- A new grading system for assessment of spirometry quality was developed.
- Standardized operator feedback options that promote synoptic reporting were developed.
- Preliminary findings derived from an international patient survey were presented.

Indications for Spirometry (1 of 2)

- 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

Indications for Spirometry (2 of 2)

- To assess patients as part of a **rehabilitation** program
- To assess risks as part of an **insurance** evaluation
- To assess individuals for **legal** reasons
- **Research** and clinical trials
- **Epidemiological** surveys
- Derivation of **reference** equations
- **Pre-employment** and lung health monitoring for at-risk occupations
- To assess health status before beginning **at-risk physical** activities

Table 1. Indications for Spirometry

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

Indications: Diagnose Asthma

- Asthma must include BOTH compatible symptoms and evidence of **variable or reversible** airflow obstruction
- Airflow obstruction from Spirometry:
  - FEV1/FVC < 70% **-- or –**
  - FEV1/FVC < LLN (Lower Limit of Normal)
- Airflow obstruction is:
  - **"Variable"** Fluctuations in symptoms or lung function over time **-- or –**
  - **"Reversible"** Improvement in FEV1 by 200 mL and 12% with albuterol
- Scooped flow volume loop
- Spirometry as part of Methacholine, or Bronchial, Challenge Test
  - FEV1 drop by 20%
- Video: www.Thoracic.org > Professionals > Clinical resources > Best of ATS Video Lecture Series > 2017 Confirming a Diagnosis of Asthma

Relative Contraindications

- Performing spirometry can be physically demanding. The forced expiratory maneuver used in spirometry increases intrathoracic, intraabdominal, and intracranial pressures.
- Caution must be used for patients with medical conditions that could be adversely affected by these physiological consequence.
- **Spirometry should be discontinued if the patient experiences pain during the maneuver.**
- Patients with potential contraindications that would prevent testing in the primary care setting may be tested in a pulmonary function laboratory where operators are more experienced and there may be access to emergency care if needed.

Table 2. Relative Contraindications for Spirometry

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

Spirometry should be discontinued if the patient experiences pain during the maneuver. Relative contraindications do not preclude spirometry but should be considered when ordering spirometry. The decision to conduct spirometry is determined by the ordering healthcare professional on the basis of their evaluation of the risks and benefits of spirometry for the particular patient. Potential contraindications should be included in the request form for spirometry.

Calibrations

- Calibration verifications must be undertaken *at least* **daily**
- **3-Liter** Calibration syringe
  - At least three times to give a range of flows: 0.5 to 6 seconds
- Accuracy **(± 2.5%**), linearity, repeatability
- **3 factors**: Temperature, barometric pressure, and time of day
  - BTPS adjustment
- Spirometers are now required to meet International Organization for Standardization (ISO) standards

3-Liter Calibration Syringe

Infection Control

- CDC Standard Precaution
  - Hand Hygiene – User & Patient
  - PPE – mask, glove, gown
  - Respiratory Hygiene/Cough Etiquette
  - Environmental Infection Prevention and Control
- Transmission-Based Precautions
  - Known or suspected
  - covid, cystic fibrosis, bronchiectasis, tuberculosis, hemoptysis, oral lesions

- Manufacturers instructions
- Single patient Use:
  - filters (bacterial-viral)
  - mouthpieces
  - nose clips

Possible Precautions

- **Reserving equipment** for the sole purpose of testing infected patients
- Testing such patients at the **end of the workday** to allow time for spirometer disassembly and disinfection
- Testing patients in their **own rooms** with
  - Adequate **ventilation** -
  - **Negative pressure**

Operator

Three key elements:
- Instrumentation
- Patient
- Operator

Requires:
training
experience

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

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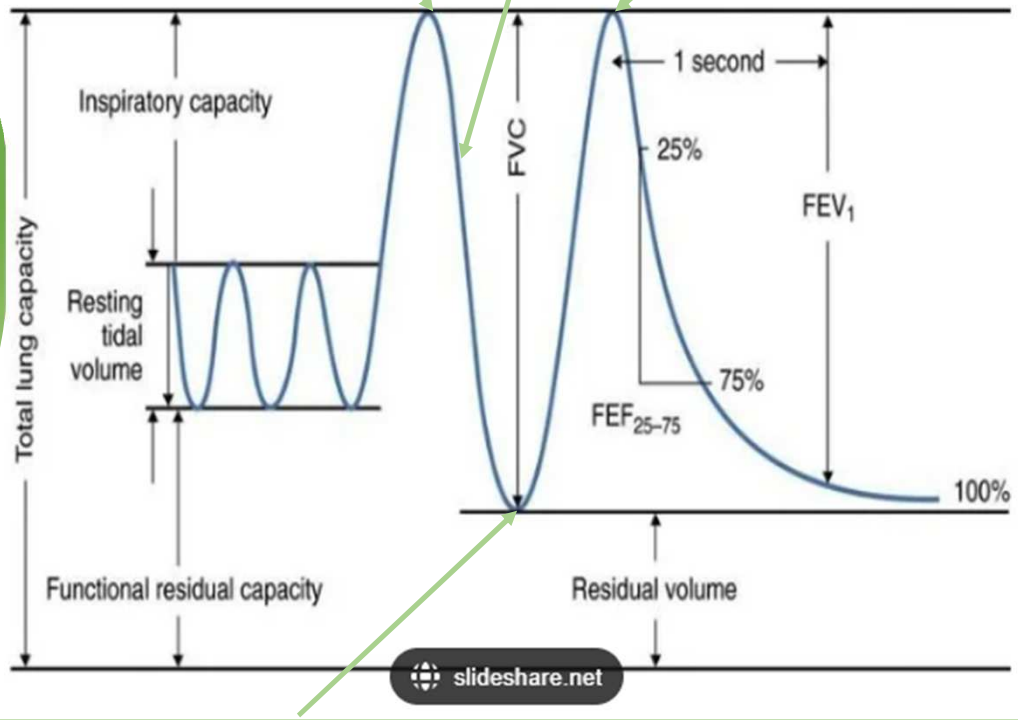
Four Maximums "Within Maneuver"

Maximal (#2) Blast of expiration – FEV1

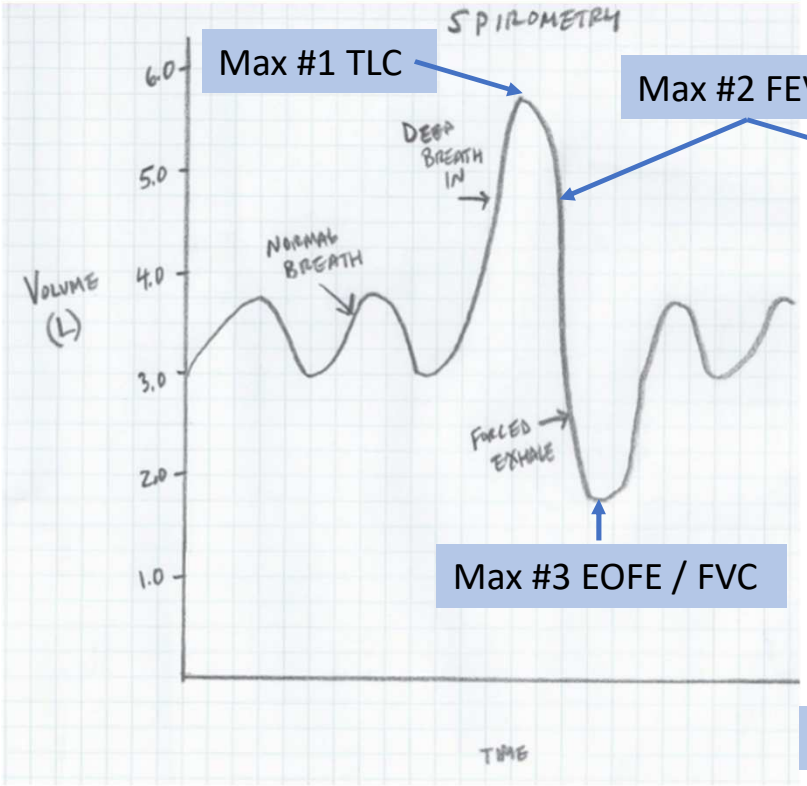
Maximal (#1) Inspiration - TLC

Maximal (#4) Inspiration – FIVC



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

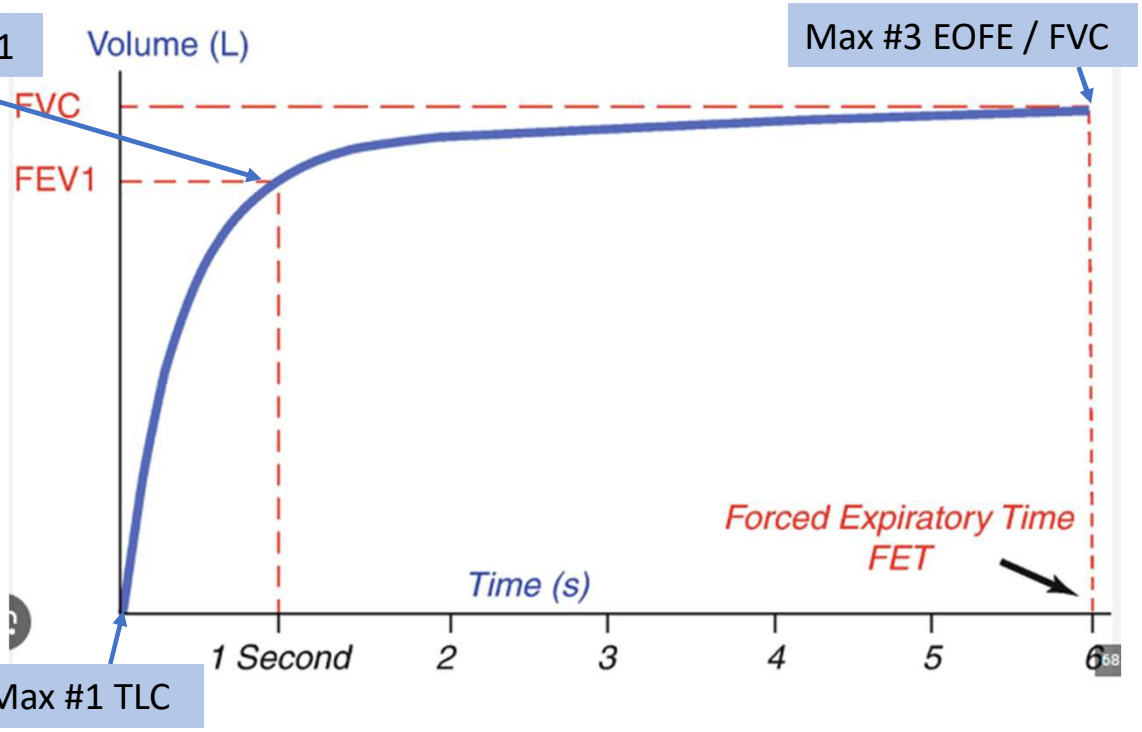
4 Maximums: Volume – Time Curve



Max #1 TLC

Max #2 FEV1

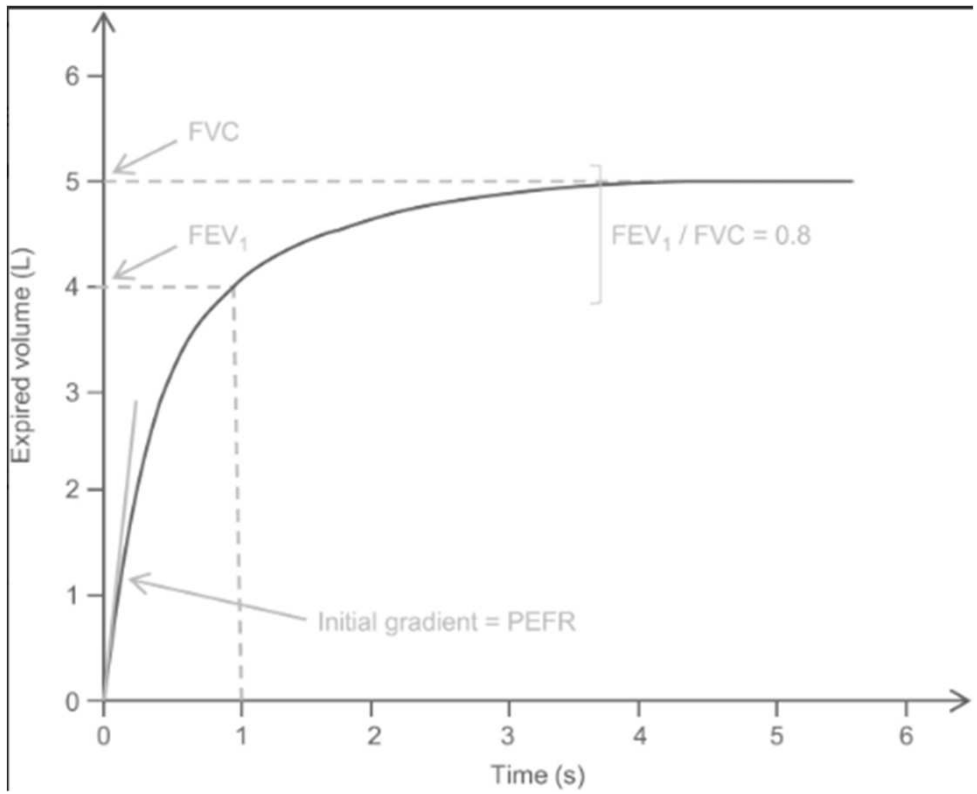
Max #3 EOFE / FVC



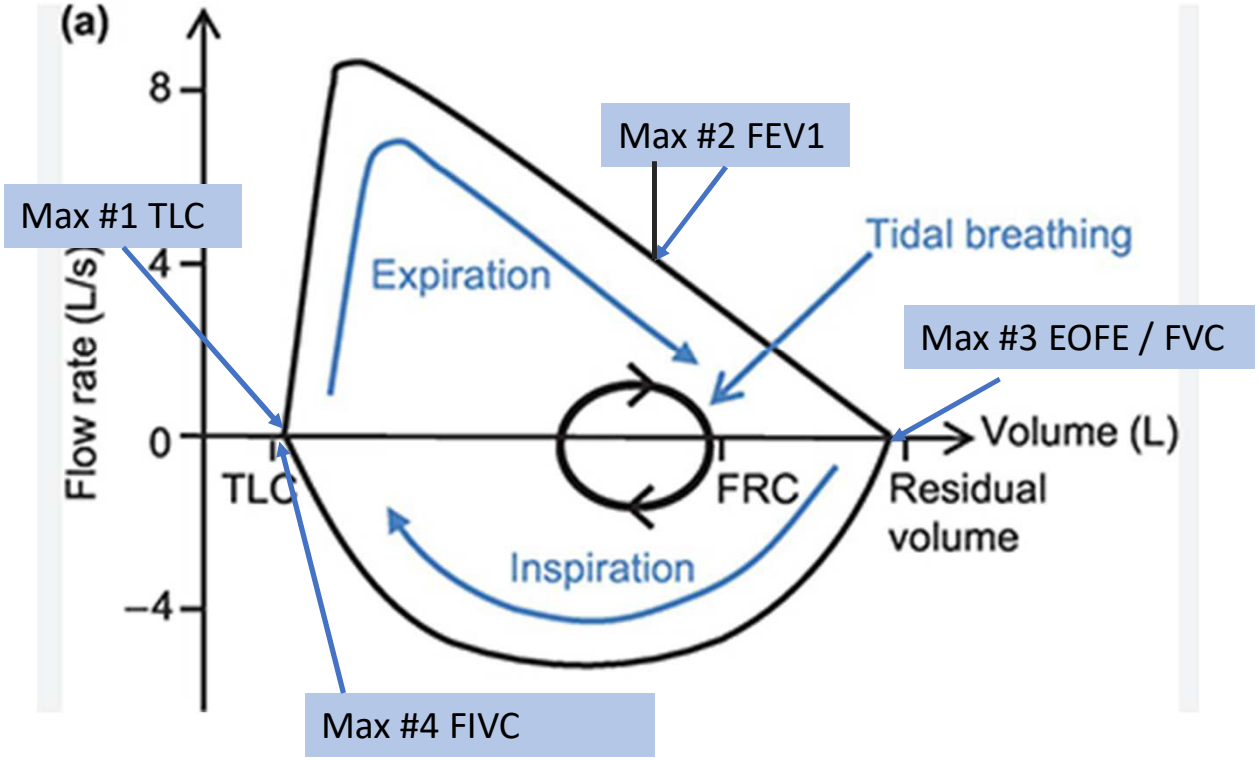
Max #3 EOFE / FVC

Max #1 TLC

Terminology: Volume – Time Curve



4 Maximums: Flow Volume Loop



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  - as part of the spirometry **procedure**

4 Maximums as part of the:

Spirometry Procedure

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

Procedure - Prepare the Patient: Key Messages from Patient Survey

- Pts would like quiet, comfortable space, with privacy, when doing spirometry
  - embarrassed at their difficulty
  - embarrassed at their coughing and sputum production
- Pts said operators need to be friendly, encouraging, and have empathy before, during, and after
- Pts feel preparation for what is going to happen is important, as well as coaching through
- **Pts don't want to have to ask for water, tissues & sputum pots**
- Pts would like recovery periods between maneuvers and to not feel rushed
- Pts would like somewhere to sit to recover for a few minutes afterwards

Procedure - Prepare the Patient: Test Prep

- **Offer the restroom!**
  - Stress incontinence in older women
- Patients should be as relaxed as possible before and during the tests.
  - Leave in well-fitting dentures
  - No gum or anything else in mouth
- Medication withholdings
  - Per referring provider
  - Purpose of testing
    - Pre- & Post- Bronchodilator
    - Therapeutic response
- Activities avoided:
  - Smoking/vaping – 1 hr
  - Intoxicants – 8 hr
  - Vigorous exercise – 1 hr
  - Avoid or loosen tight-fitting clothing
- Morning coffee is ok

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

- The height must be measured against a wall or **stadiometer**
  - **without shoes!**
  - with the **feet together and touching the wall**
  - standing as tall as possible
  - eyes level and looking straight ahead
  - Back flush against the wall

- Height in centimeters to one decimal place or in inches
- 25 years or older - within 1 year

- *Don't use the height on the driver's license!*
- *Don't use the height the patient tells you.*

Procedure - Prepare the Patient: Height is critical – con't

- For patients unable to stand erect, height may be estimated using:
  - Arm Span
  - Ulna length (preferred for children) measured with calipers (to avoid error introduced using a tape measure)
- Recognizing that there are sex, age, and ethnic differences in such estimates..

Procedure - Prepare the Patient: Wt, Age, Sex, Race

- Weight:
  - wearing indoor clothes
    - Empty the pockets
  - without shoes
  - nearest 0.5 kg or in pounds
  - BMI: kg/m^2
- Age: calculated from DOB

- **Birth sex:**
  - Operator will **ask the patient**
  - Birth sex - not gender
    - Inaccurate entry of birth sex may lead to incorrect diagnosis and treatment
- Race / Ethnicity:
  - Operator will ask the patient
  - *Race-neutral PFT reference equations*

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

- The patient should be seated
  - Erect – ***"Sit as tall as you can"***
  - shoulders slightly back
  - chin slightly elevated
    - flowtube level to the floor
  - both feet flat on the floor
    - a smaller chair or a raised footstool should be provided for children and small adults
- A chair
  - with arms to prevent falling sideways should syncope occur
  - without wheels
  - with a height adjustment so that the feet are flat on the floor

Procedure - Prepare the Patient: Patient Posture - cont

- If testing is undertaken with the patient in any position other than sitting, this must be documented in the report.
- Standing
- Fowler's position *(elevated head and torso)*
- Crook's position *(knees raised)*
- Supine

- For subjects with tetraplegic spinal cord injury, FVC and FEV1 were higher in supine than while sitting

4 Maximums as part of the procedure:

Instruct and Demonstrate:

- *Position of the mouthpiece and nose clip to avoid leaks*
- Instruct or Explain
  - Using words to **tell** the patient
- Demonstrate
  - Using action / behavior to **show** the patient
- Normal / Easy tidal breathing
- **Four Maximums**
- Ask for and answer patient questions
- Confirm that patient understands and is willing to comply

Procedure - Instruct & Demonstrate: Four "Within Maneuver" Maximals

- Maximal (#1) Inspiration - TLC
  - **"Breathe in FAST all the way to a completely full lung"**
- Maximal (#2) Blast of expiration – FEV1
  - **"Blast out hard and fast- use all the force possible"**
- Maximal (#3) End Of Forced Exhalation (EOFE) – FVC
  - **"Keep blowing out all your air; past where you feel that you cannot blow out any longer"**
- Maximal (#4) Inspiration – FIVC
  - **"Breathe in FAST all the way to a completely full lung"**

Procedure - Instruct & Demonstrate: Four "Within Maneuver" Maximals

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

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

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

  Maximal **(#3)** Exhale - EOFE / FVC

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

  Maximal **(#2)** Blast out expiration – FEV1

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

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

4 Maximums as part of the procedure:

Coach Maneuver: Overview

- *Have patient assume the correct posture*
- **“Mouthpiece & Nose clip”**
- **“Normal Breathing”**
- **“Deep breath IN…more…more”**
- **“Blast hard”**
- **“Keep breathing out…out…out”**
- **“Deep breath back in”**

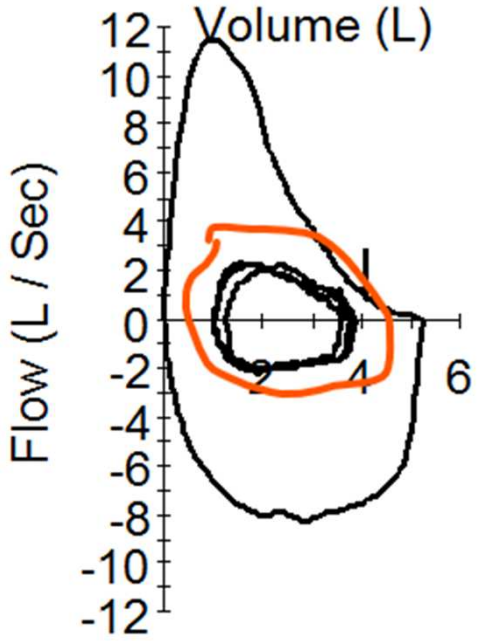
Procedure - Coach Maneuver: Posture, "Mouthpiece & Nose clip"

- Have patient assume the correct posture:
  - Both feet flat on the floor
  - Sitting erect – not touching the back of the chair, shoulders back
    - Do NOT lean forward
  - Chin slightly elevated – Mouthpiece & filter level to floor
    - Do NOT put chin down
  - Looking straight ahead

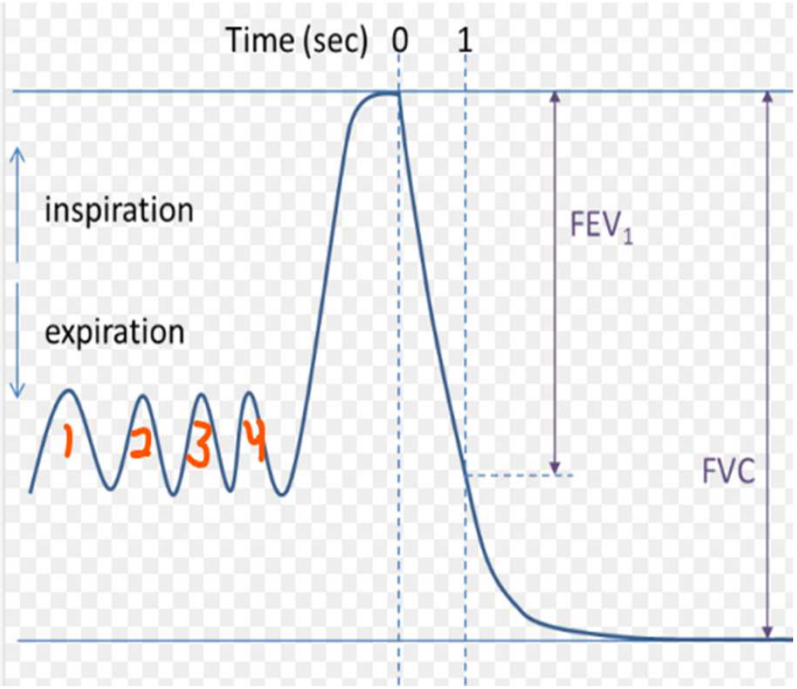
- **"Mouthpiece & Nose clip"**
  - NO LEAK!
    - in or out
  - Multiple "sniff" attempts
    - Confirm no leak at the nose
    - Hold nose with fingers
    - Alcohol wipe
  - Mouthpiece between teeth
    - Don't bite down – occlude airway
  - Lips tight around mouthpiece

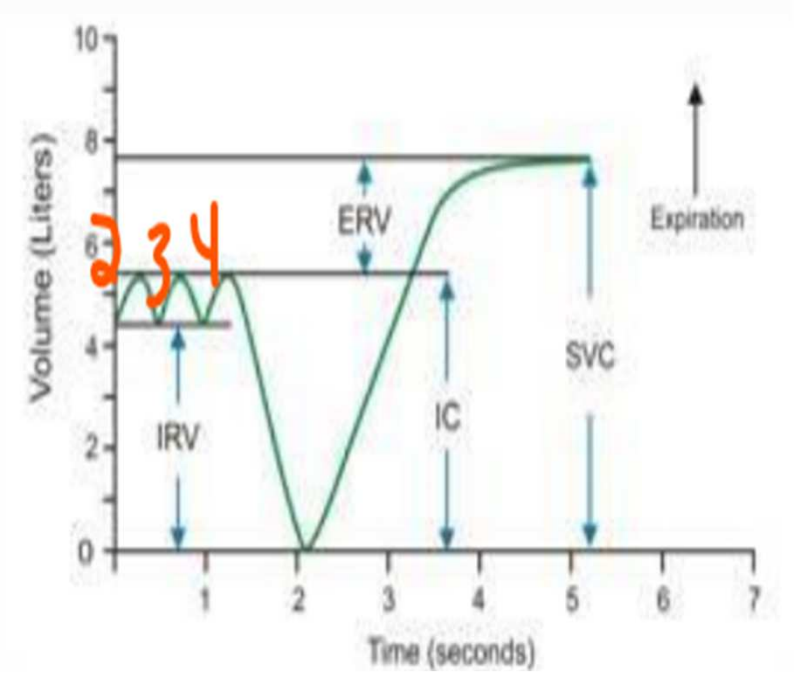
Procedure - Coach Maneuver: “Normal Breathing”

- “Breathe normally” or “Normal Breathing” or “Easy Breathing”
  - tidal breathing
- Looking for a nice steady baseline
  - Clear out inconsistent breaths
  - Stability : at least three tidal breaths with end-expiratory lung volume within 15% of the Vt.
  - Watch the Flow-Volume Loop for overlaying tidal breaths moving R or L:
    - Leaking?
    - Stacking?
    - Zero-flow offset?
  - Watch the Volume-Time graph for similar sized & shaped tidal volume breaths evenly spaced



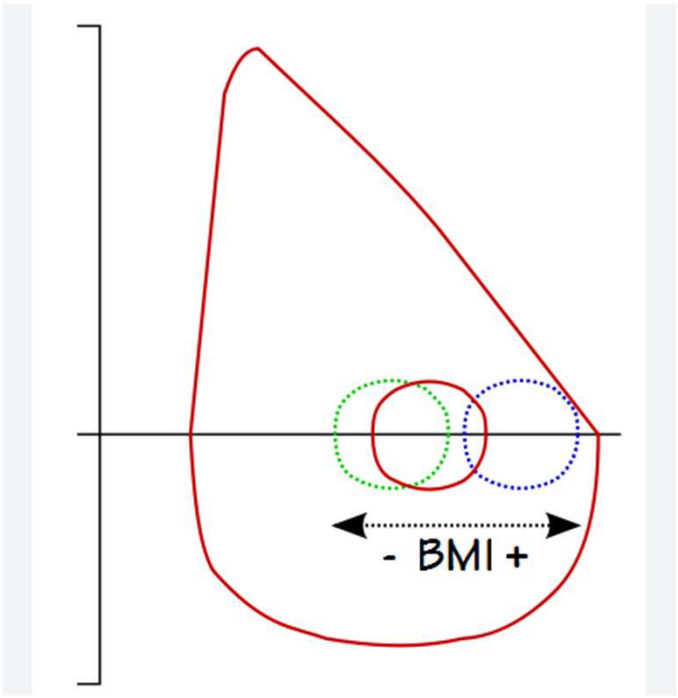
Procedure - Coach Maneuver: Tidal Breathing



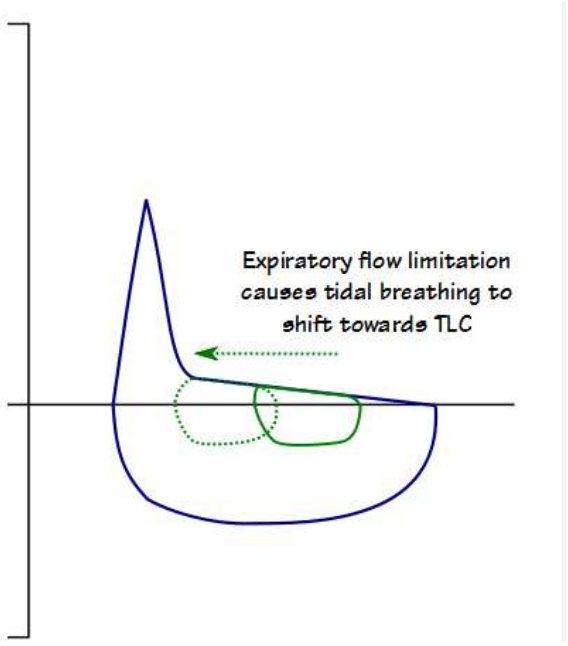


Note: FVL & Tidal breath

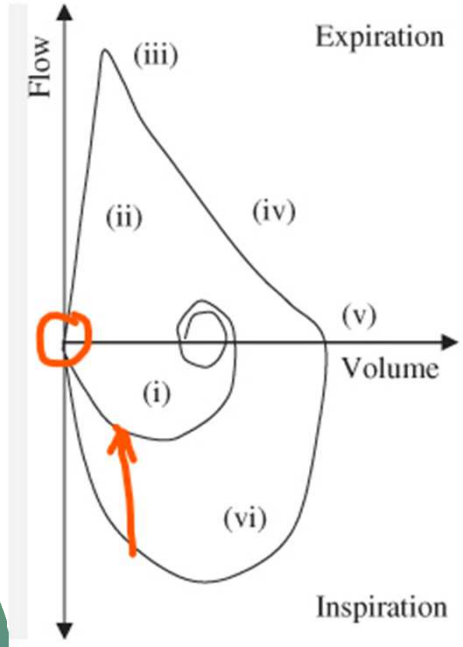
BMI



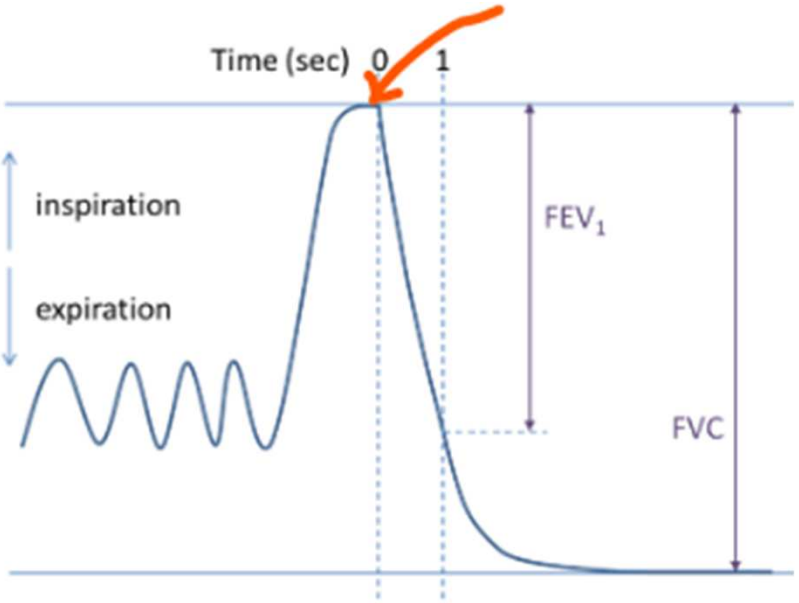
Expiratory Flow Limitation

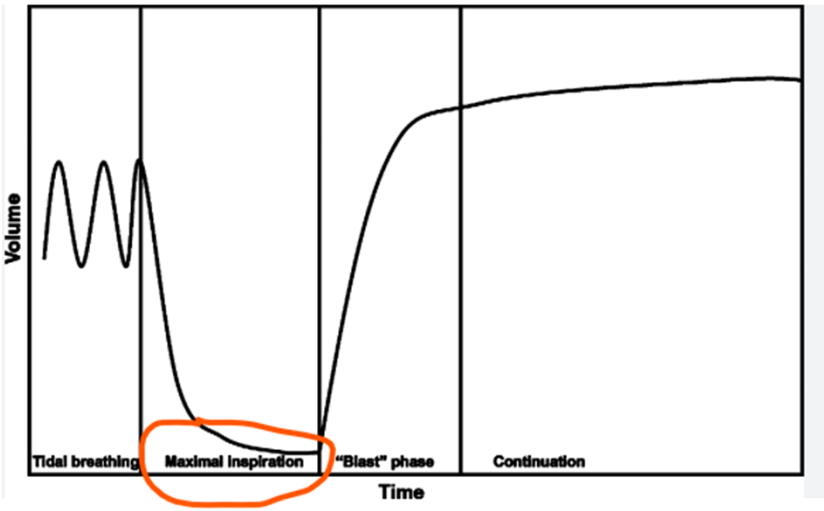


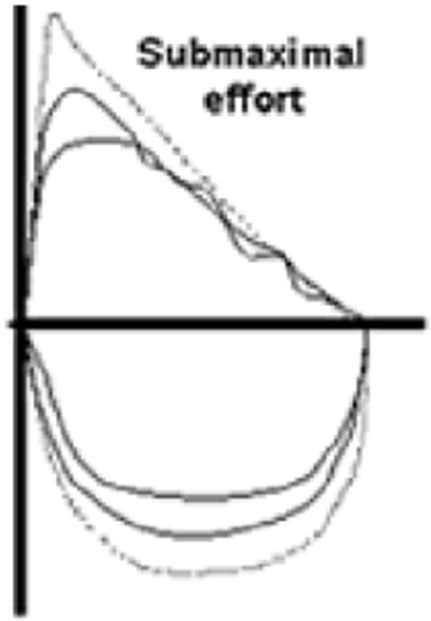
Procedure - Coach Maneuver: "Deep Breath IN" Max (#1) - TLC



- Inspire completely and rapidly with a pause of ≤ 2 s at TLC
- **"(Big) Deep breath IN"**
  - **"…more, more, more"** – to TLC
- Indicators of maximal inspiration include:
  - Eyebrows raising
  - Eyes widening
  - Head quiver / bobble
  - A patient who looks comfortable is NOT likely to be at full inflation.
- Inspiratory F-V loop *(below the X-axis)* comes up gradually, sloping, all the way back to the "0" point
    - NOT straight line up to X-axis


Time (sec) 0 1
inspiration
expiration
FEV1
FVC

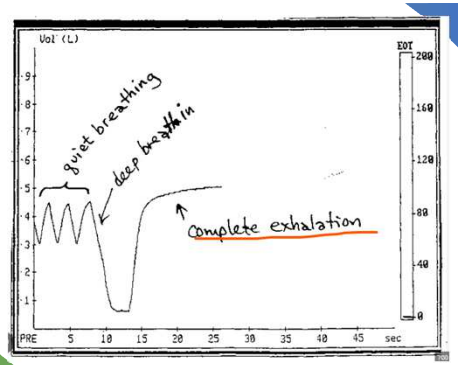

Volume
Tidal breathing
Maximal inspiration
"Blast" phase
Continuation
Time



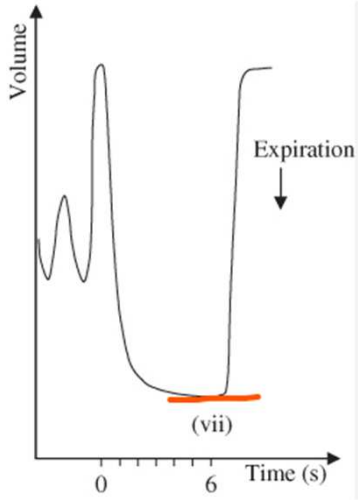
Procedure - Coach Maneuver: "Blast Hard" Max (#2) – FEV1

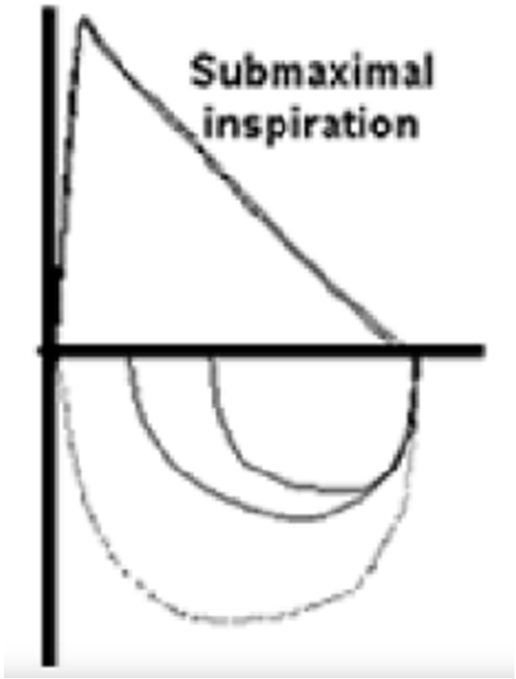
- **"Blast out hard"** – FEV1
  - Not just "Blow"
  - Expire with maximal effort / Hard / Fast
  - Stay sitting up straight; do not lean forward or head down
- Looking for a sharp peak in Flow-Volume loop
  - very early *(left / close to the Y-axis)*
  - Rounded peak is sub-maximal effort and should 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

- Have patient assume the correct posture
- Attach nose clip
- Inspire completely and rapidly with a pause of ≤ 2 seconds at TLC
- Place mouthpiece in mouth and close lips around the mouthpiece
- Expire with maximal effort until no more air can be expelled while maintaining an upright posture – confirm EOFE
- Repeat instructions as necessary, coaching vigorously
- Repeat for a minimum of three maneuvers, usually no more than eight for adults
- Check FEV1 and FVC repeatability and perform more maneuvers as necessary

Learning Objectives

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

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

4 Maximums & Within-Maneuver Acceptability and Usability

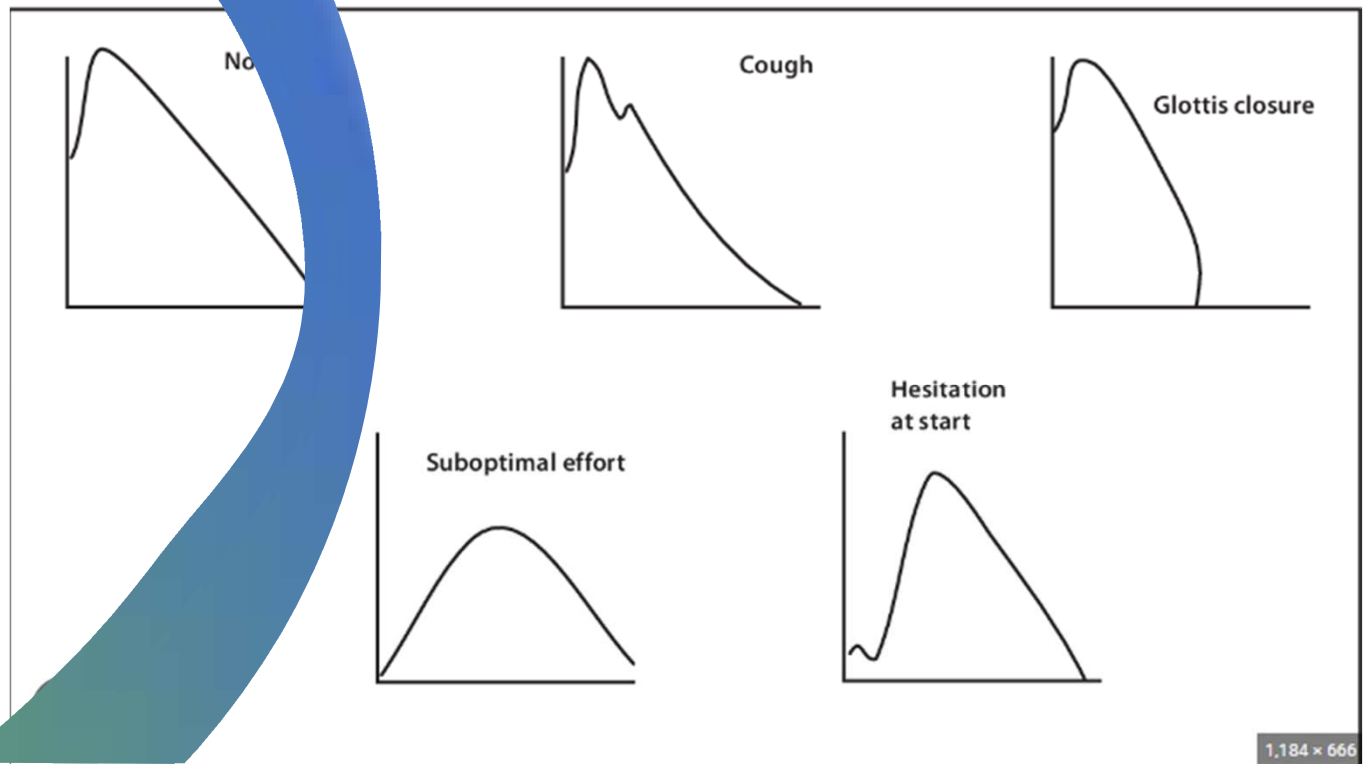
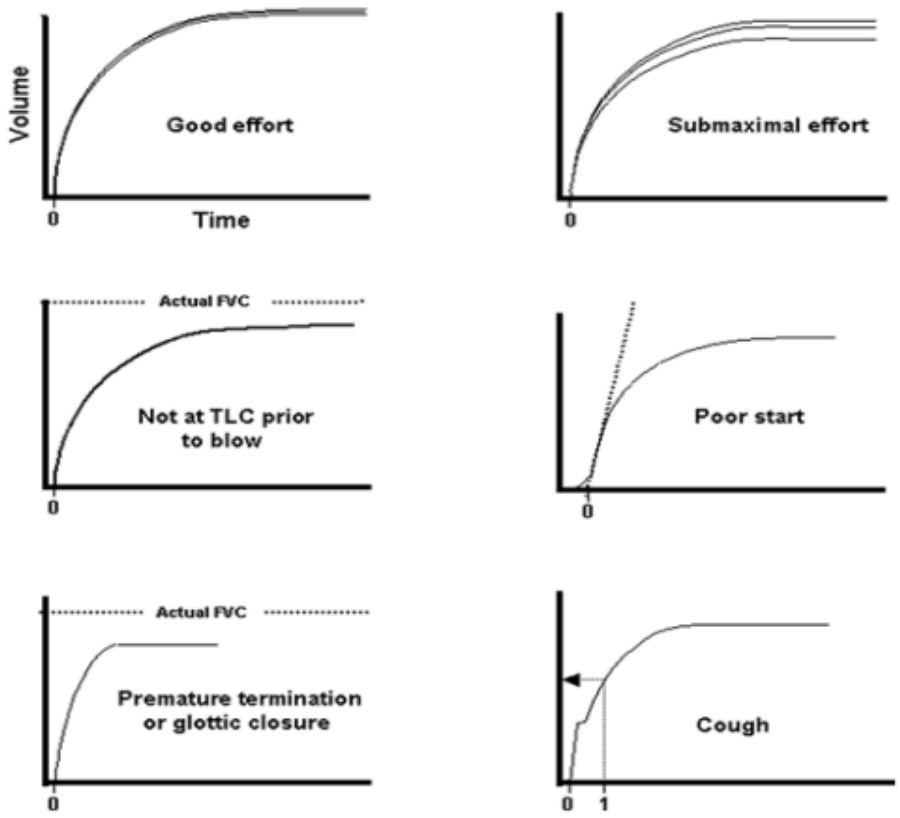


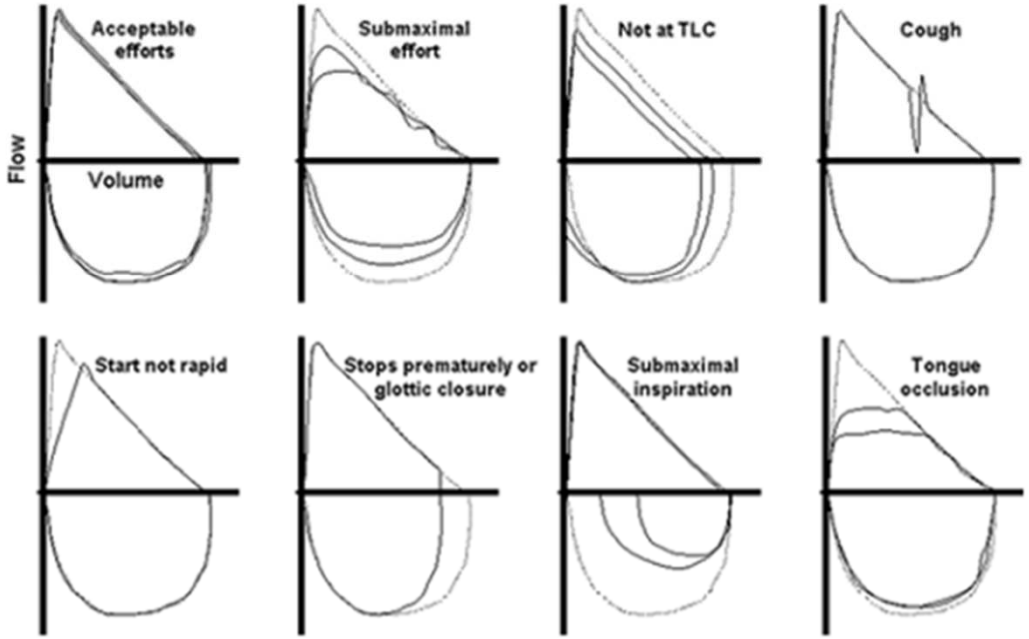
Figure 1. Volume Time examples of good and poor effort



4 Maximums & Within-Maneuver Acceptability and Usability

- 4 Maximums & Within-Maneuver Acceptability and Usability

Figure 2. Flow Volumes Curve examples of good and poor effort



4 Max's – Within-Maneuver Acceptability & Usability

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

Acceptability and Usability Criterion	Required for Acceptability		Required for Usability	
	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 Max's - Within-Maneuver Acceptability: TLC

- Starting from
  - end of normal tidal exhalation or
  - resting expiration level or
  - FRC level
- Up to maximum Inspiration level
- Maximal volume
- Maximal speed ?

- M

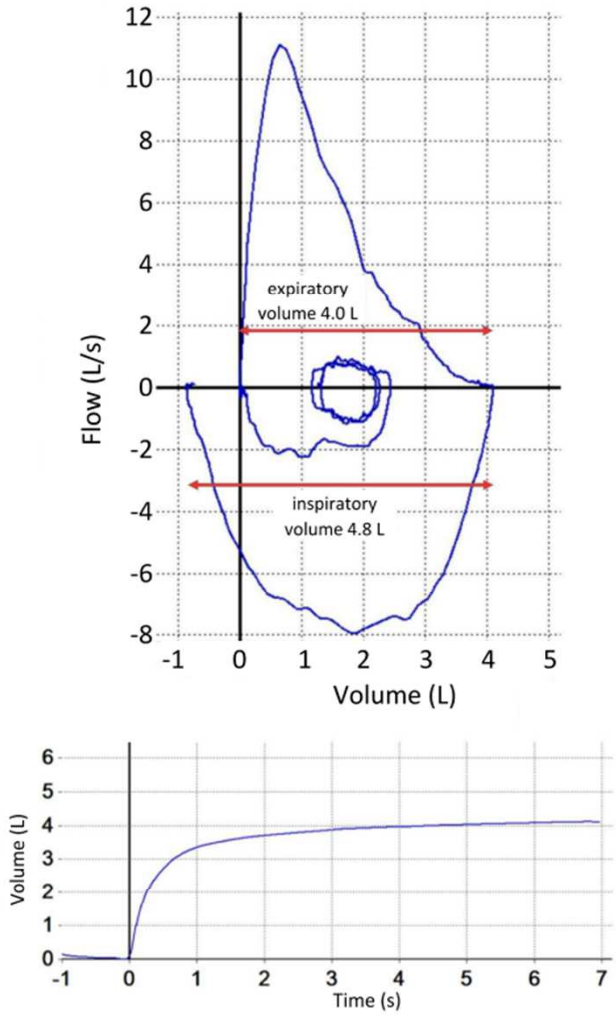
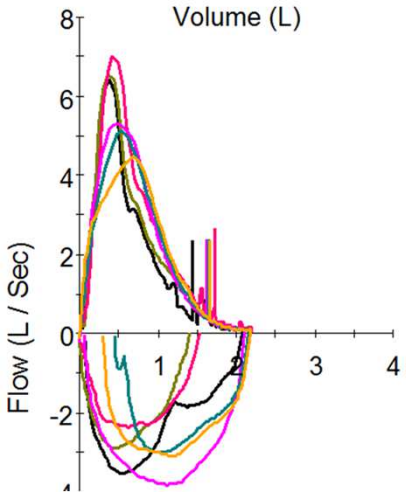


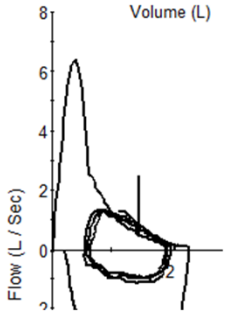
Figure E10. When the inspiratory volume at the end of the maneuver exceeds the forced expiratory volume, the subject did not reach total lung capacity before blowing out. The maneuver is not acceptable if the inspiratory volume exceeds the FVC by more than 0.100 L or 5% of FVC, whichever is greater.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

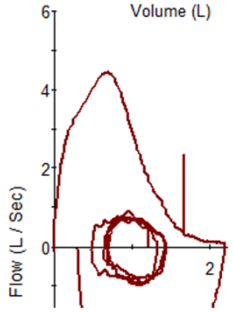
4 Max's - Within-Maneuver Acceptability: FEV1

- START of FEV1 Blast
  - From maximal Inspiration level
  - a.k.a. Start of Exhalation
  - a.k.a. Back Extrapolation (BEV)
  - Time Zero
    - Delayed Start / Hesitation
    - False Start / Leak



- PEAK of FEV1 Blast
  - Rise
  - Sharp – Maximal effort
  - Rounded – Sub-maximal effort





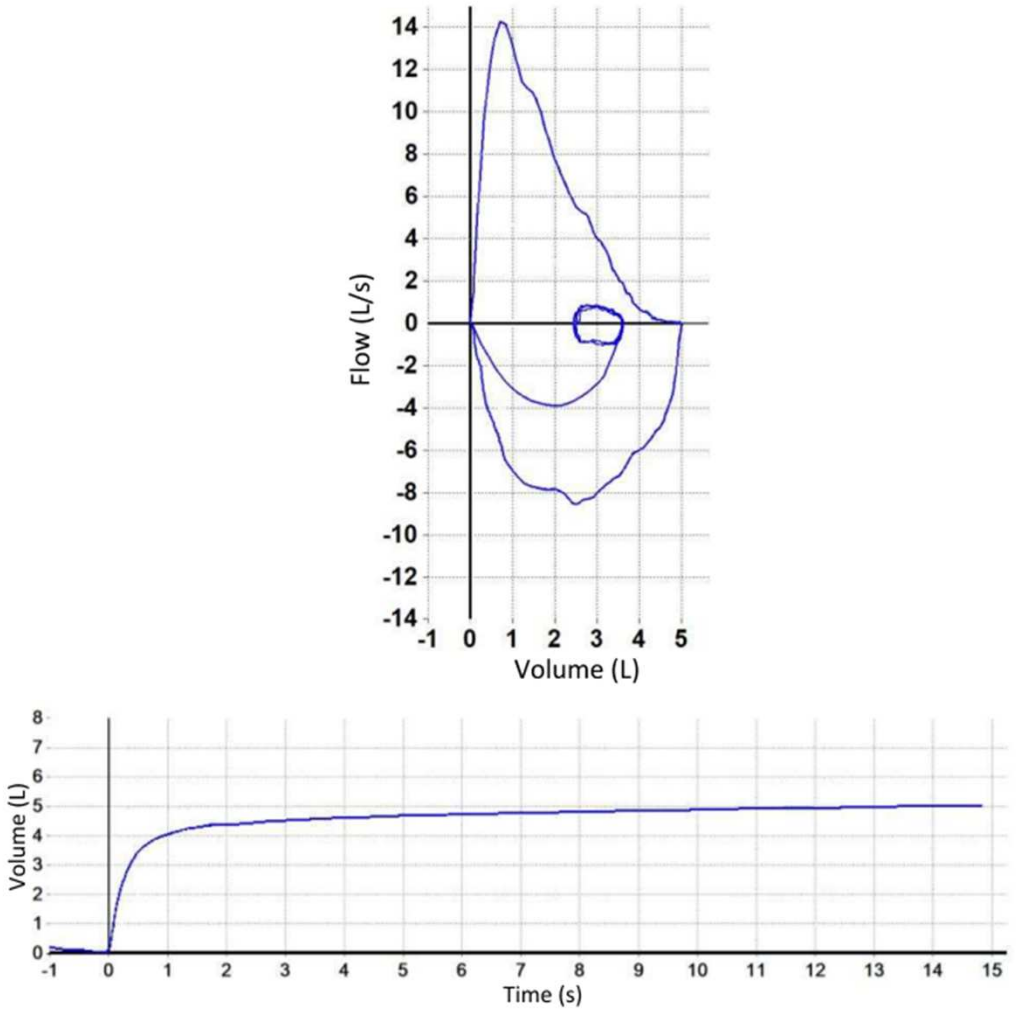


Figure E1. An acceptable maximal maneuver by a normal male (age 68.4 yr). The flow-volume graph has a fast start and sharp peak with a smooth drop to zero flow. There is a steep slope at the start of the volume-time curve with a plateau at the end of expiration. *(reproduced with permission – RESPTREC™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

Max #2 FEV1 – Start of FEV1 Blast: Delayed Start / Hesitation </> 2 sec

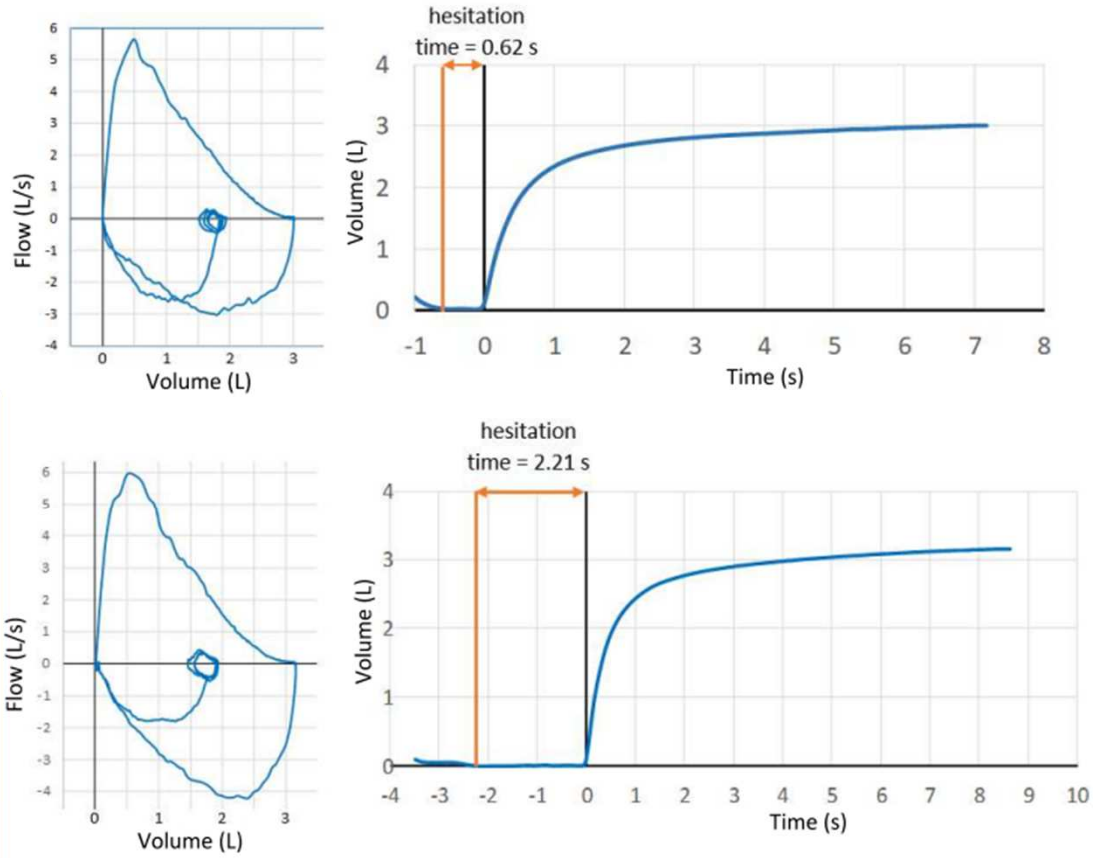
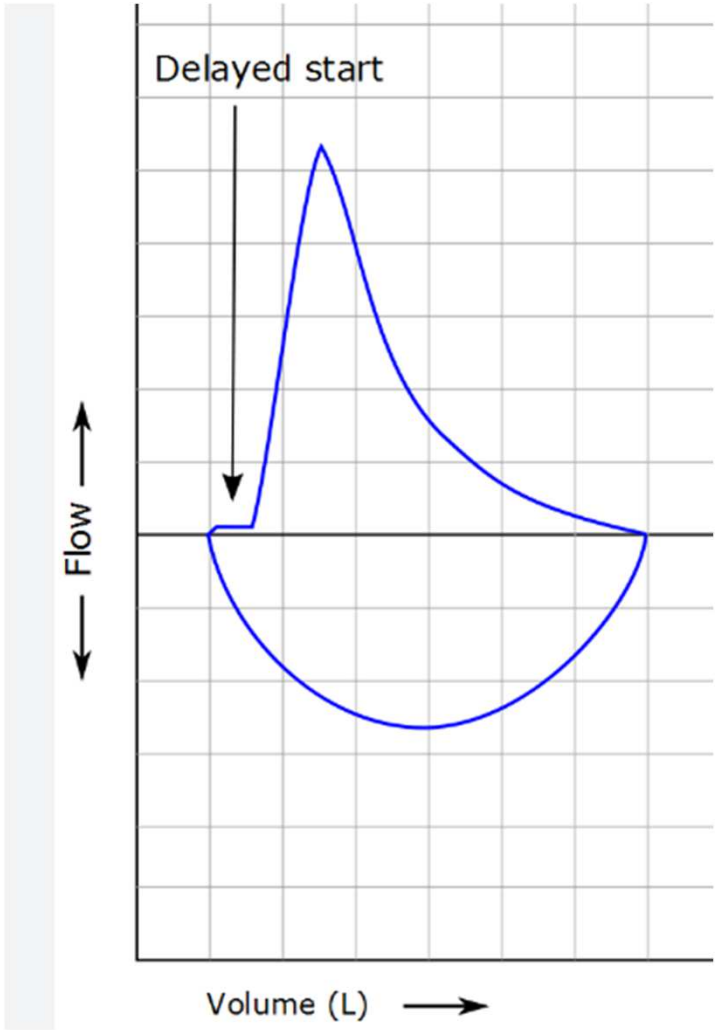


Figure E13. Hesitation time is defined as the time from attaining maximum inspired lung volume to the back-extrapolated time zero which should be less than 2 s. The upper panel shows an acceptable maneuver with a hesitation time of 0.62 s. The lower panel shows a maneuver from the same person but with 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)

Max #2 FEV1 – Start of FEV1 Blast: False Start / Leak </> 5% or 0.1 L (*whichever is greater*)

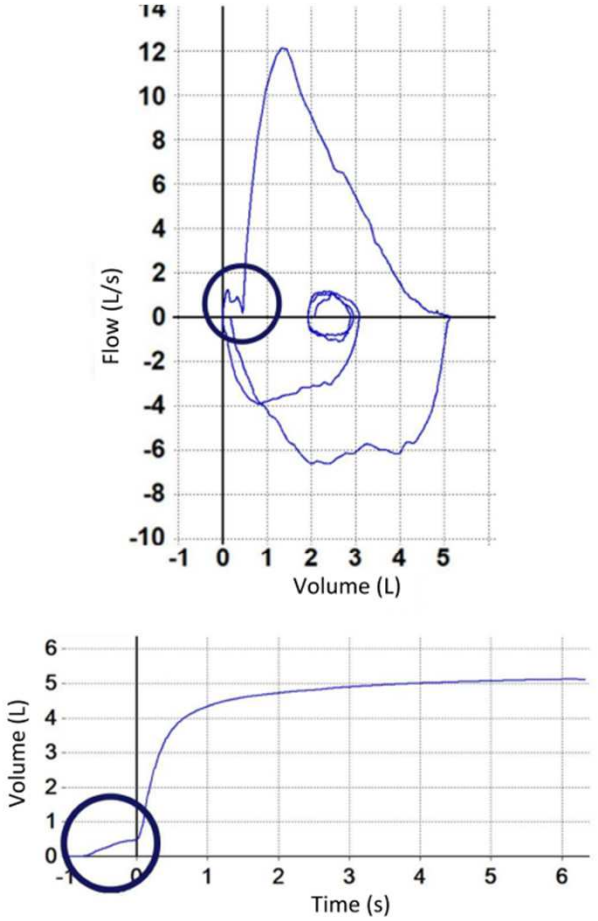
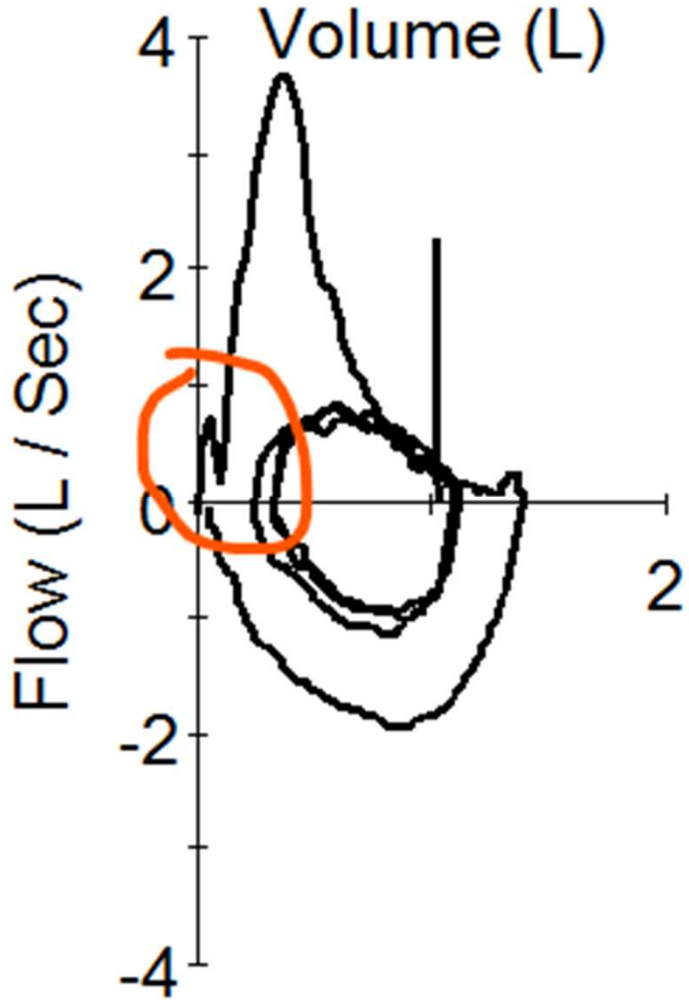


Figure E8. A false start occurs when the subject reaches total lung capacity and leaks out some air before beginning a forced expiration. In this example the back extrapolated volume is 0.475 L which exceeds 5% of FVC and therefore the FVC and FEV1 are unacceptable. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*


Volume (L)
4
2
0
-2
-4
2
Flow (L / Sec)

Back Extrapolated Volume

Must have BEV <5% of FVC or 0.100 L, whichever is greater

Within-Maneuver Acceptability:
Start of FEV1 Blast - Back-Extrapolated Volume (BEV)

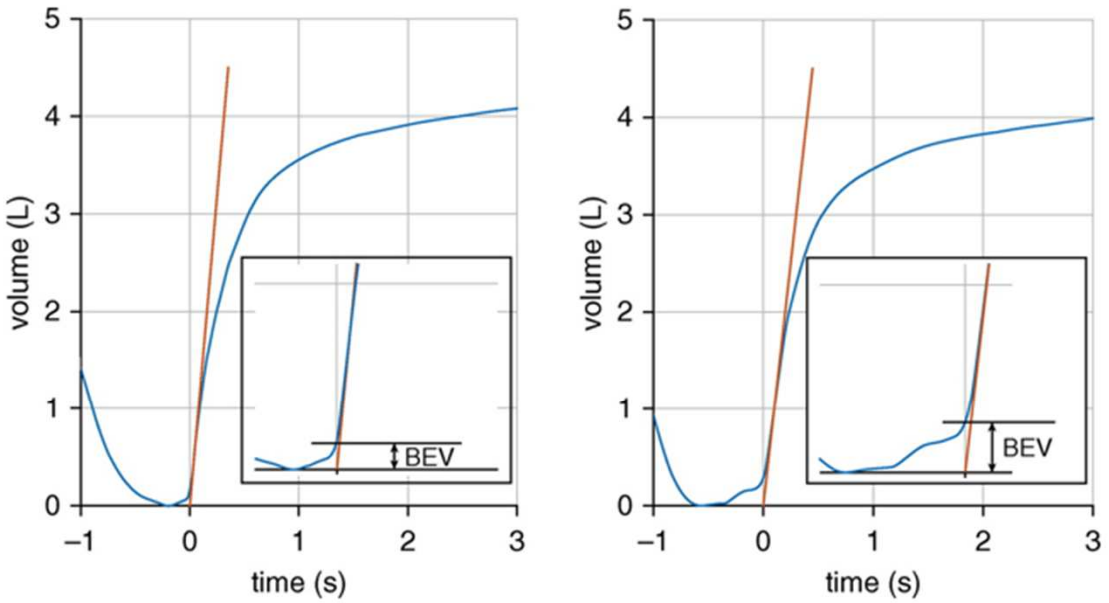


Figure 1. Back-extrapolated volume (BEV). Time 0 is found by drawing a line with a slope equal to peak flow through the point of peak flow (red line) on the volume–time curve and setting Time 0 to the point where this line intersects the time axis. The BEV is equal to the volume of gas exhaled before 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.

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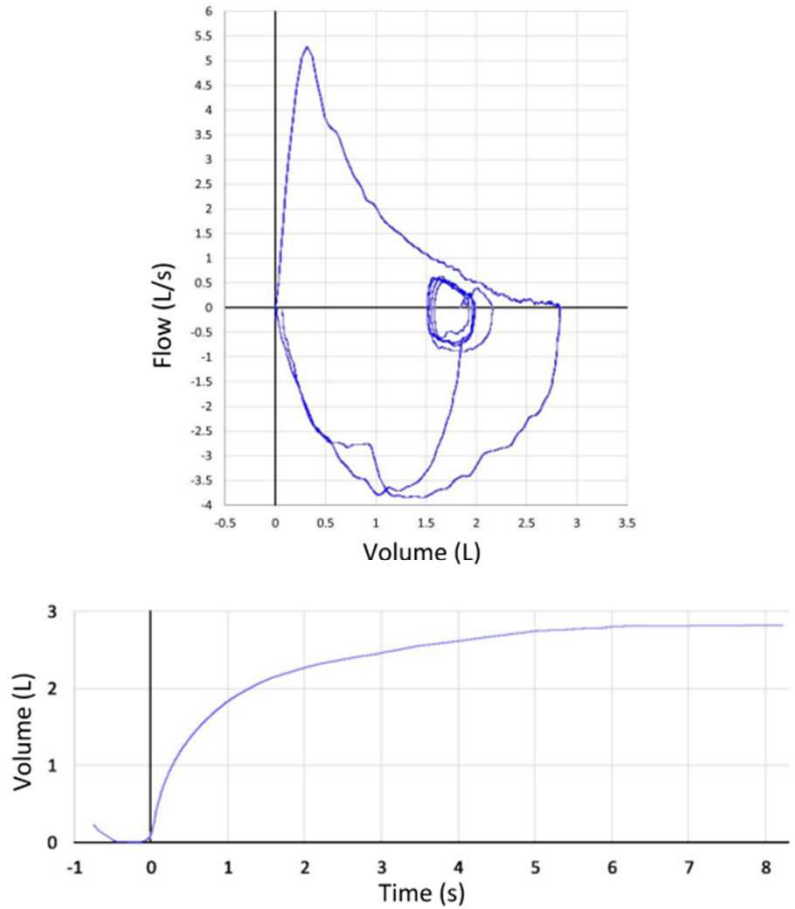
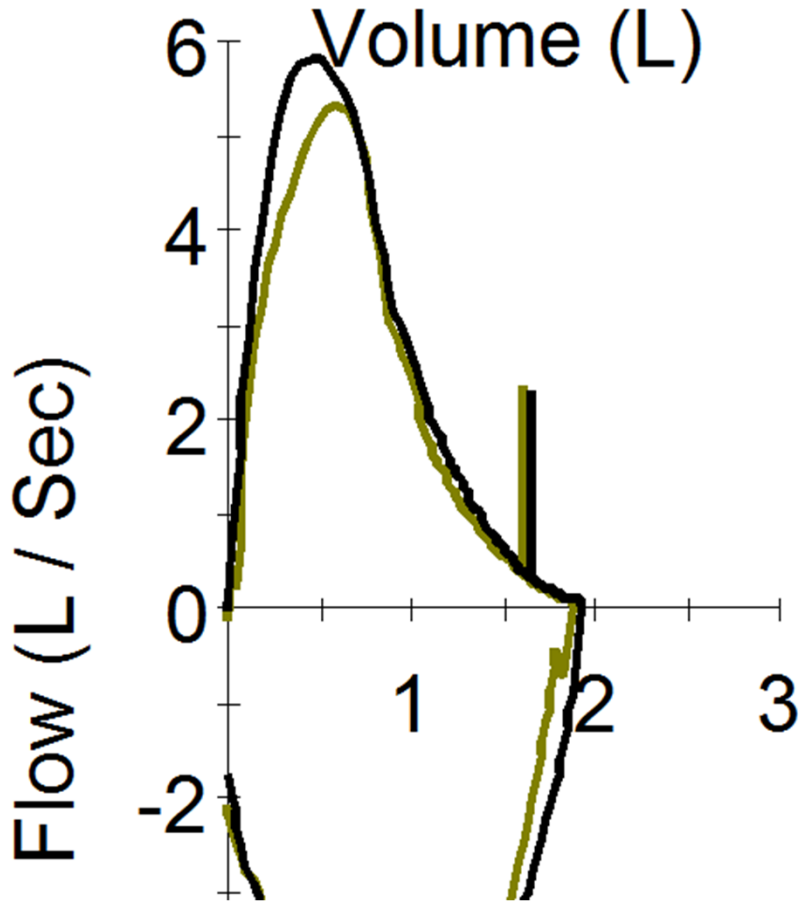
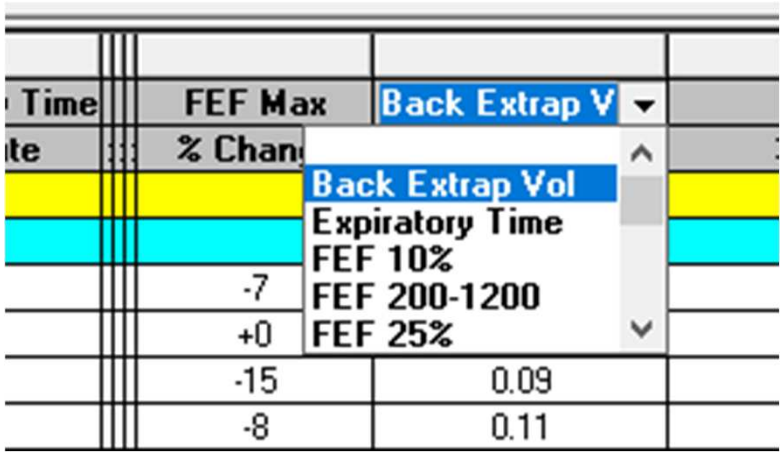
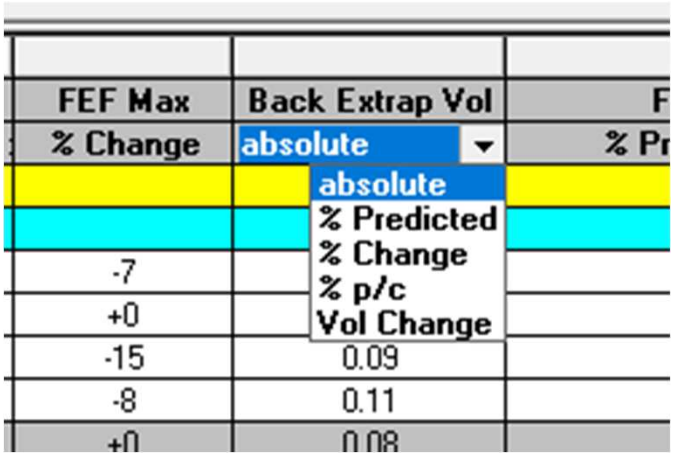


Figure E5. An acceptable maximal maneuver by a male (age 11.0 yr) with uncontrolled asthma. Note the concave shape of the expiratory flow-volume curve. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*


Volume (L)
6
4
2
0
-2
1
2
3
Flow (L / Sec)

MGC Breeze


Time
FEF Max
Back Extrap V
te
% Chan
Back Extrap Vol
Expiratory Time
FEF 10%
FEF 200-1200
FEF 25%
-7
+0
-15
0.09
-8
0.11


FEF Max
Back Extrap Vol
% Change
absolute
absolute
% Predicted
% Change
% p/c
Vol Change
-7
+0
-15
0.09
-8
0.11
+0
0.08

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

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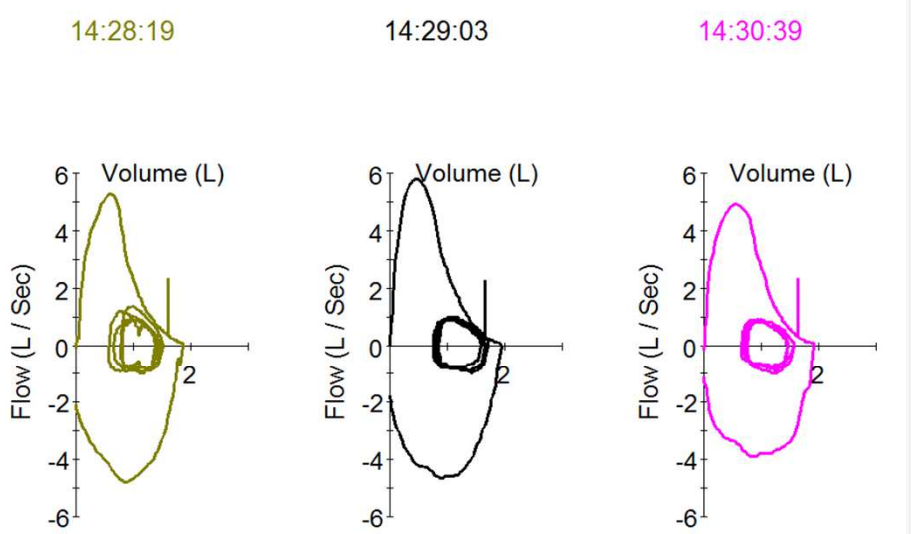
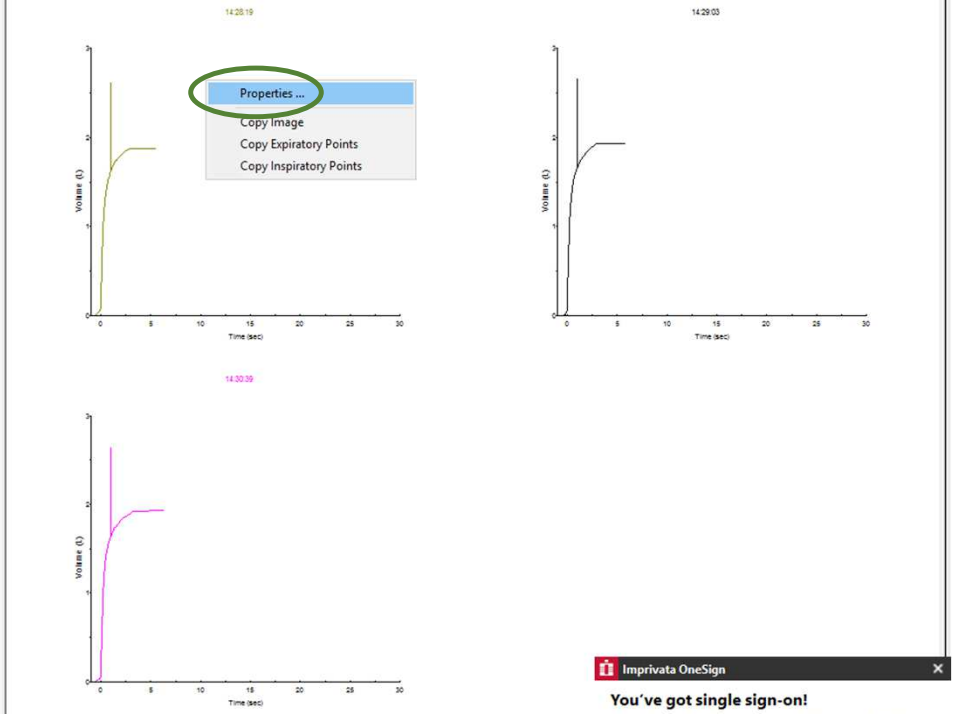
Calibrate | Zero Flow | Start | Stop | 00:00:00 | Pre

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	





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

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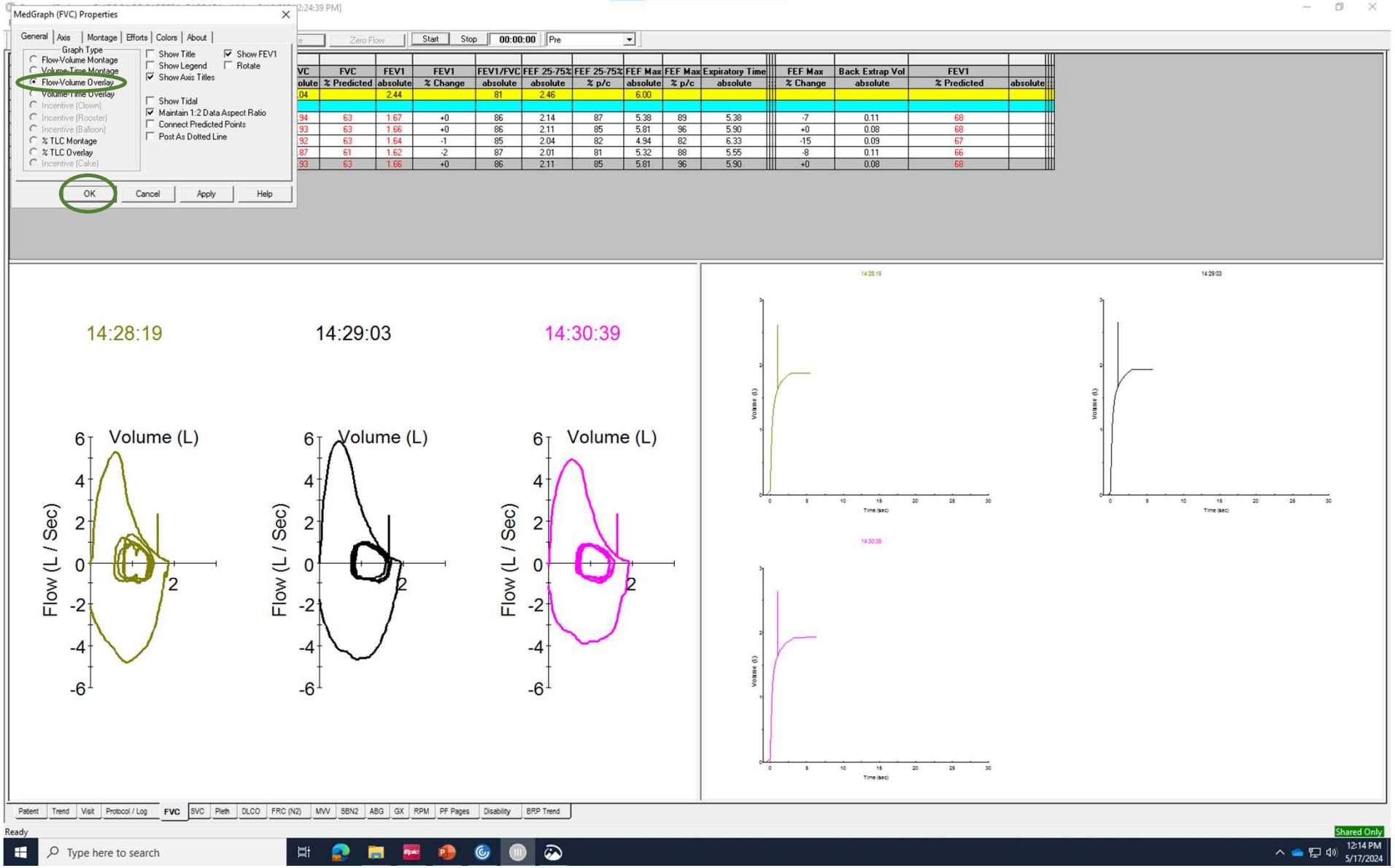

VC olute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute	FEV1 % Predicted	absolute
.04		2.44		81	2.46		6.00						
.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11	68	
.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08	68	
.92	63	1.64	-1	85	2.04	82	4.94	82	6.33	-15	0.09	67	
.87	61	1.62	-2	87	2.01	81	5.32	88	5.55	-8	0.11	66	
.93	63	1.66	+0	86	2.11	85	5.81	96	5.90	+0	0.08	68	

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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
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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	

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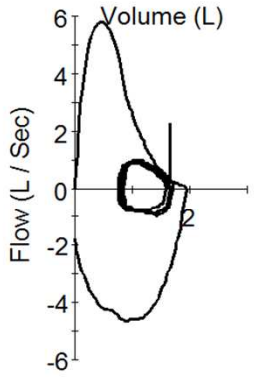

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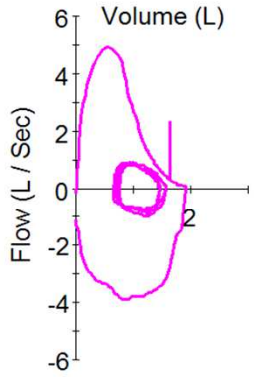

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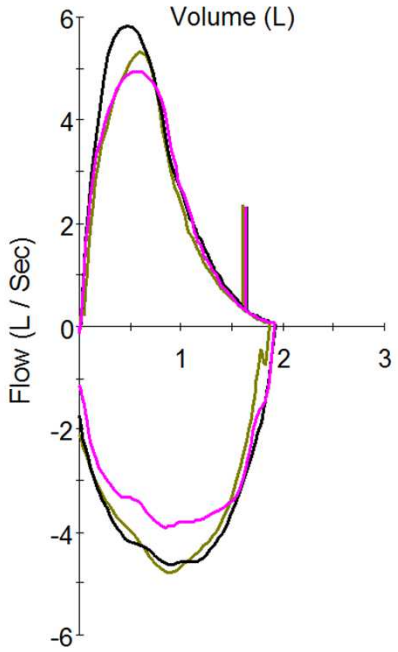

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Time	Select	I-Lp	Test Mode	ATS	ATS	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute	FEV1 % Predicted	absolute
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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	

Calculator

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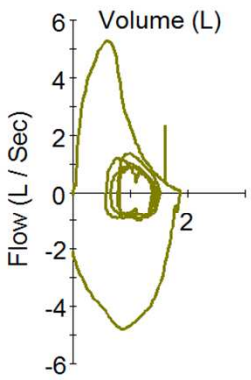

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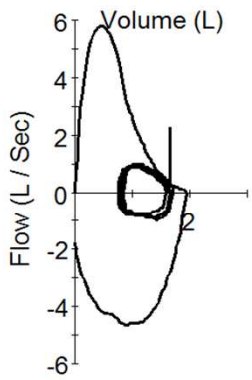

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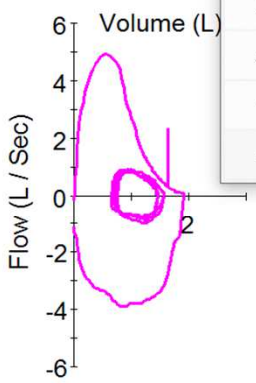

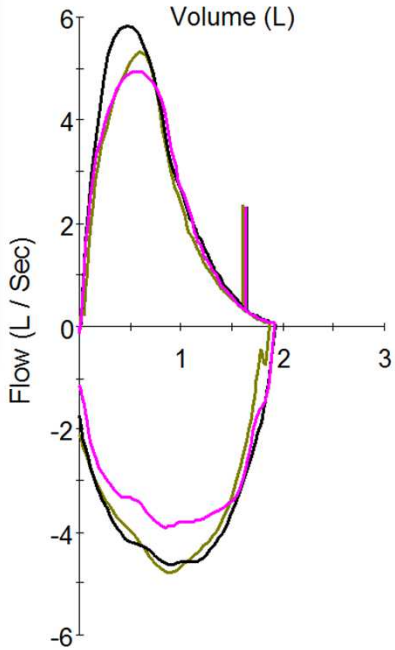

Patient | Trend | Visit | Protocol / Log | FVC | SVC | Pleth | DLCO | FRC (N2) | MVV | SBN2 | ABG | GX | RPM | PF Pages | Disability | BRP Trend

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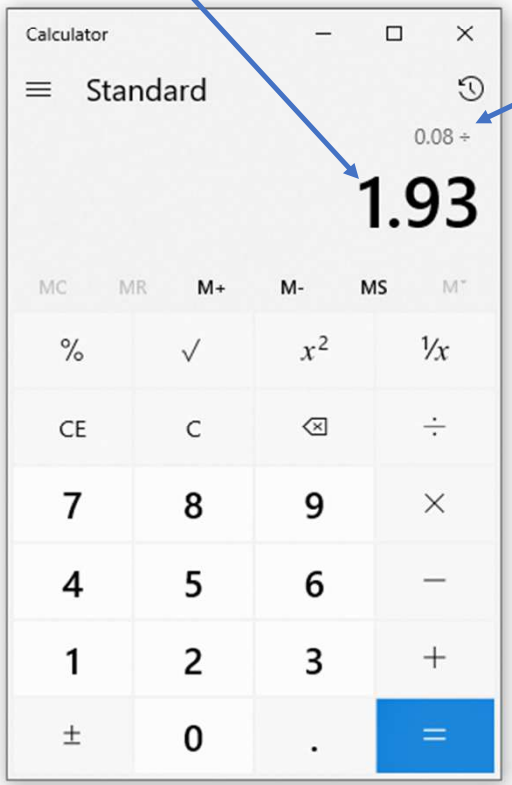
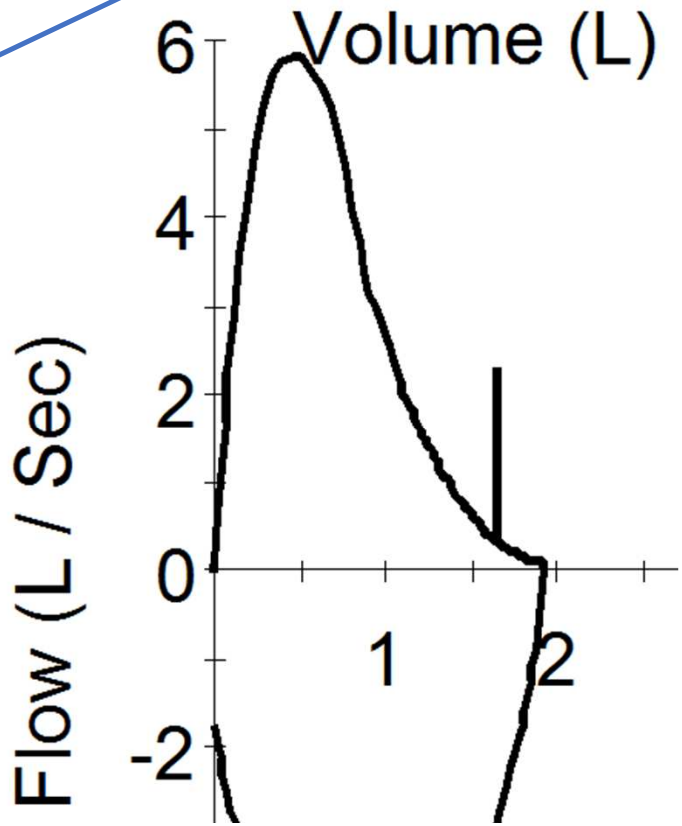
ATS	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute
	3.04		2.44		81	2.46		6.00				
	1.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11
	1.93	63	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

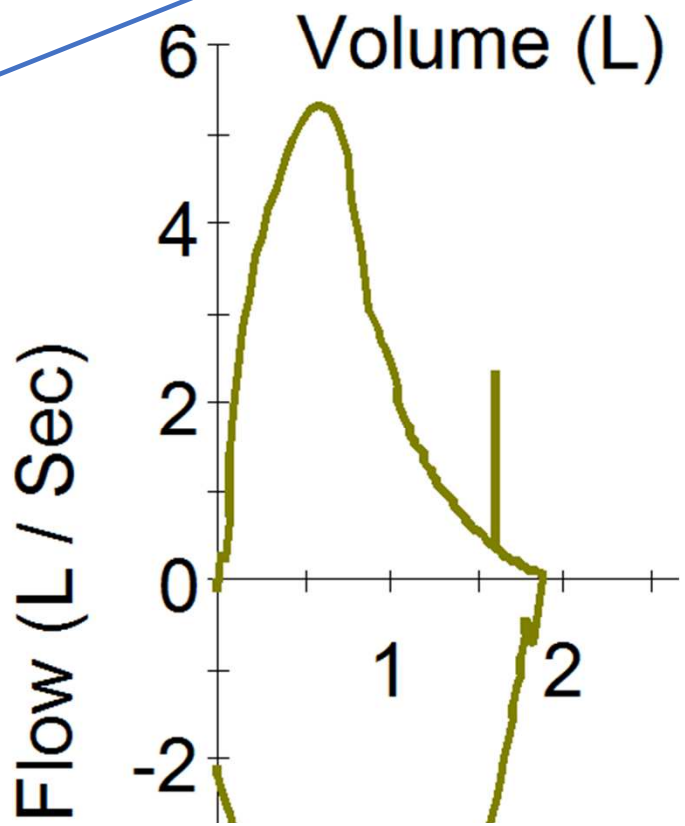




ATS	FVC absolute	FVC % Predicted	FEV1 absolute	FEV1 % Change	FEV1/FVC absolute	FEF 25-75% absolute	FEF 25-75% % p/c	FEF Max absolute	FEF Max % p/c	Expiratory Time absolute	FEF Max % Change	Back Extrap Vol absolute
	3.04		2.44		81	2.46		6.00				
	1.94	63	1.67	+0	86	2.14	87	5.38	89	5.38	-7	0.11
	1.93	63	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



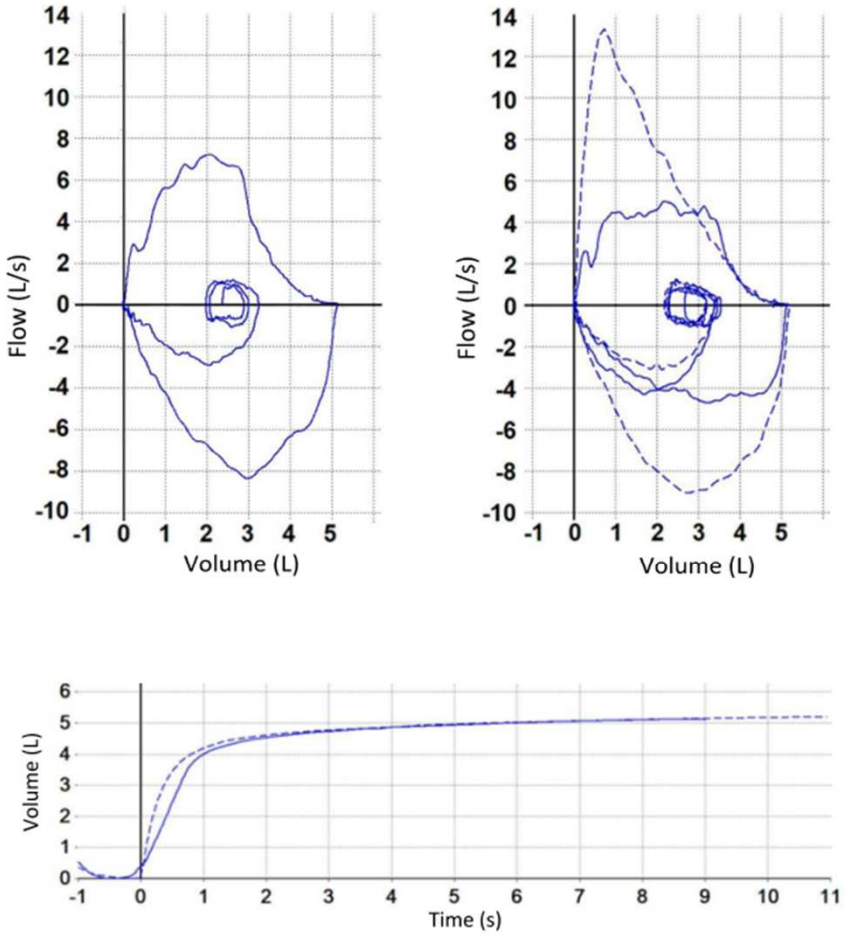
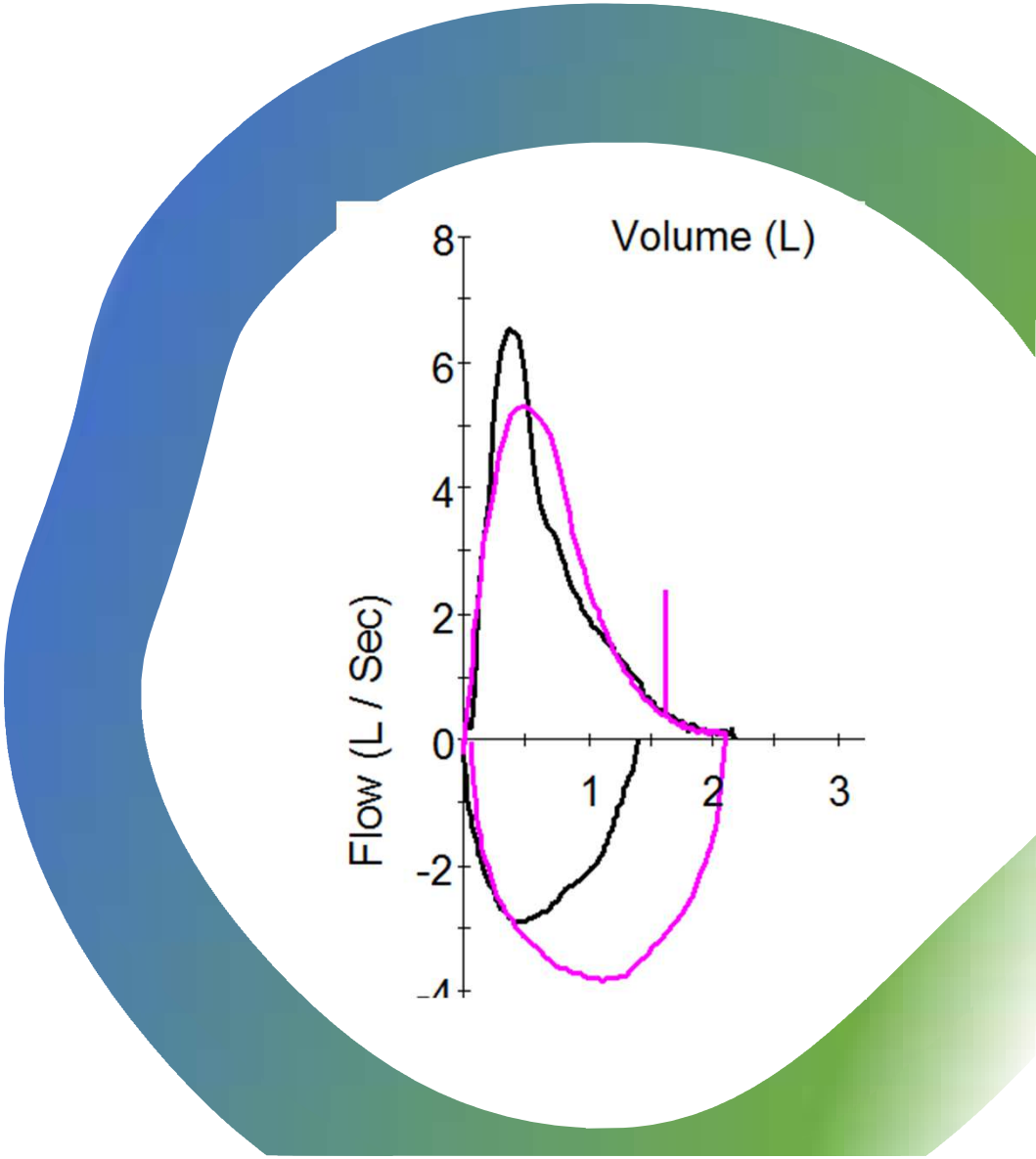


Figure E6. A sub-maximal effort is characterised by a rounded flow-volume curve and a less steep slope at the start of the volume-time curve. Compare a sub-maximal effort (solid line) to an acceptable maneuver (dashed line) in the same subject. A sub-maximal effort will often have a rise time >150 ms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

Max #2
FEV1 –
Peak:
Rise </>
150 ms

Max #2 FEV1:
Sub-Maximal Efforts



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

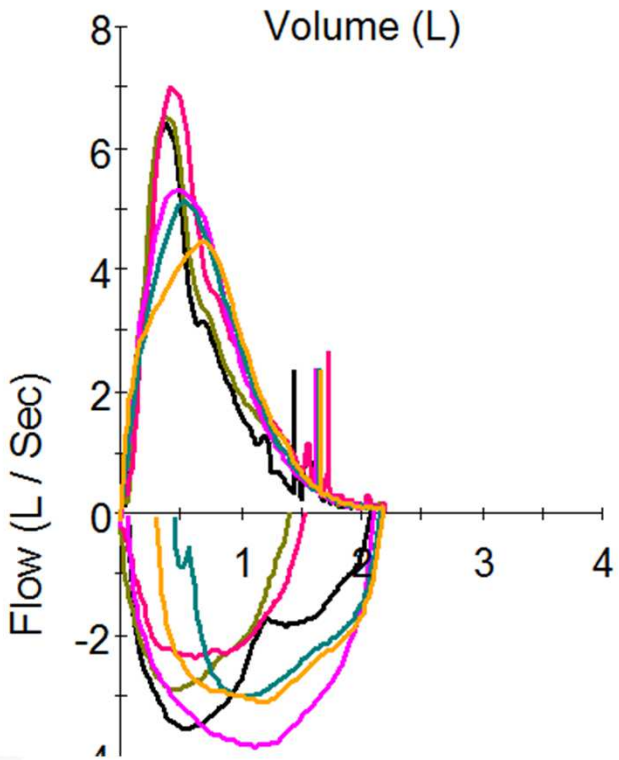
Michael J. Krowka , **Paul L. Enright** , **Joseph R. Rodarte** , and **Robert E. Hyatt**
https://doi.org/10.1164/ajrccm/136.4.829 **PubMed:** 3662235

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 Max's - Within-Maneuver Acceptability: Start of Forced Exhalation /Back-Extrapolated Volume (BEV)

Must have BEV ≤5% of FVC or 0.100 L, 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

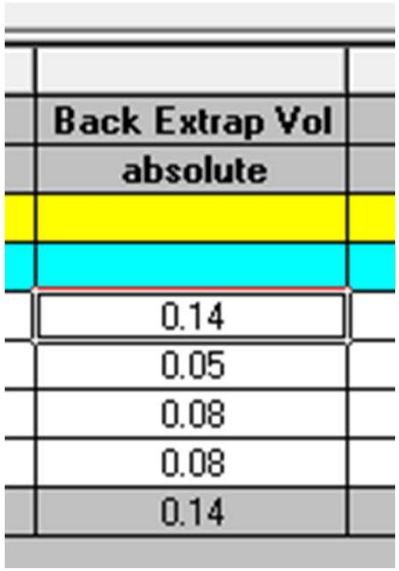
BEV value must be shown in % FVC and in Liters

Rise Time

10% - 90%

≤ 150 ms

May be > 150 ms with upper airway obstruction



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. Figure E13 shows the effects of a faulty zero-flow set procedure that renders both FEV1 and FVC neither acceptable nor usable.

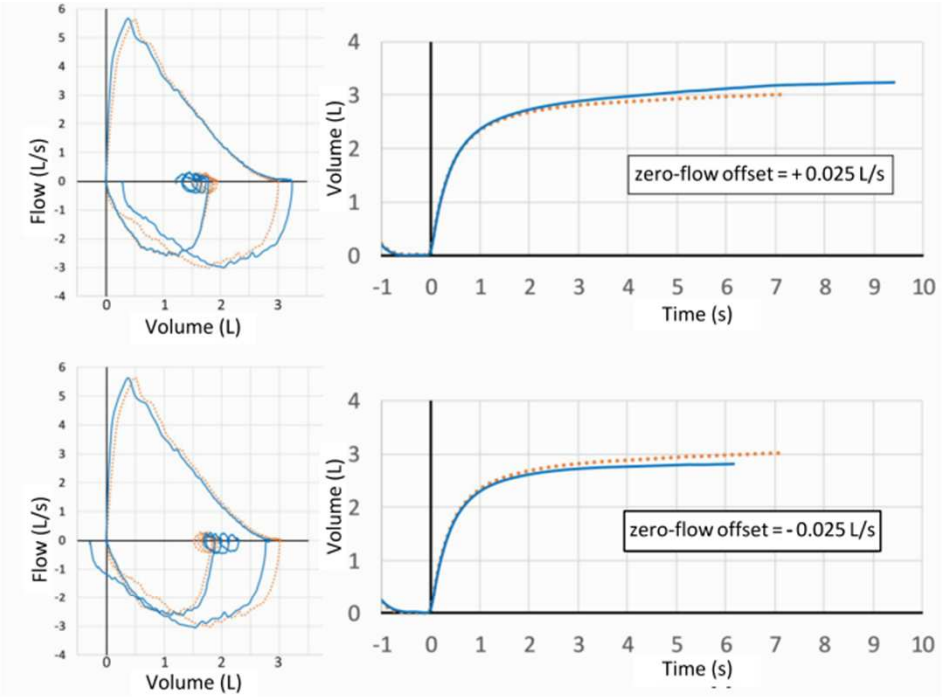


Figure E14a. The effect of a zero-flow offset caused by flow through the sensor while the system is in an auto-zero routine. These examples show simulated zero-flow offsets of +0.025 L/s (upper panel) and -0.025 L/s (lower panel). The blue lines are the simulated offsets and the dotted orange lines are the actual data with no zero-flow offset.

A positive zero-flow offset (upper panel) causes the expiratory volume to be overestimated and is seen as a steady increase in volume rather than reaching a plateau in the volume-time graph. It causes the tidal volume loops in the flow-volume graph prior to forced exhalation to progressively move to the right. A positive zero-flow offset also causes an underestimation of the inspiratory volume.

A negative zero-flow offset (lower panel) causes the expiratory volume to be underestimated and may not be obvious in the volume-time graph. The tidal volume loops in the flow-volume graph move progressively to the left. The inspiratory VC is overestimated and may be confused with a maneuver where the patient did not attain TLC before the forced expiration.

FEV_1 and FVC from maneuvers with an erroneous zero-flow offset are not acceptable.

Spirometry systems should not pass the auto-zero procedure if variable flow is detected during the procedure or if there is a significant change in the zero-flow level.

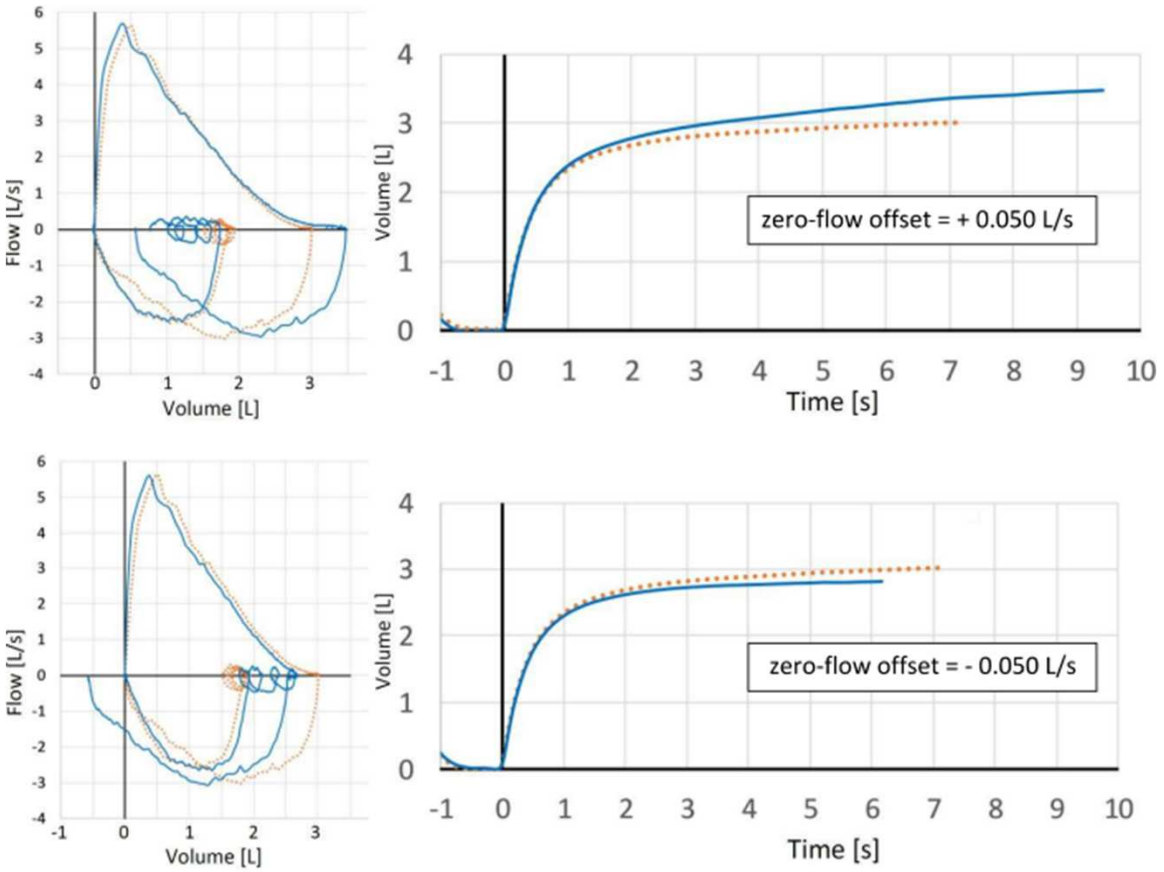
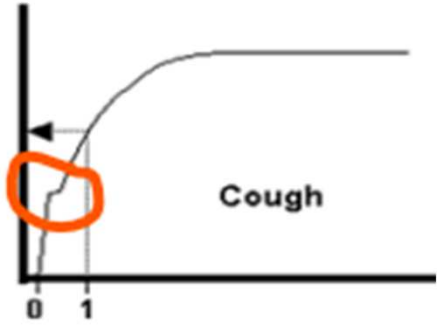
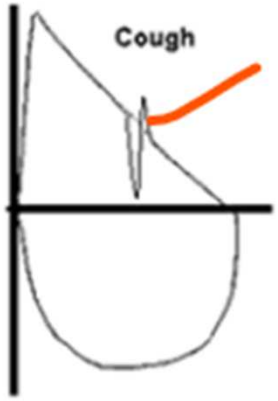


Figure E14b. A second example of the effect of a larger zero-flow offset caused by flow through the sensor while the system is in an auto-zero routine. These examples show simulated zero-flow offsets of +0.050 L/s (upper panel) and -0.050 L/s (lower panel). The blue lines are the simulated offsets and the dotted orange lines are the actual data with no zero-flow offset. The effects noted in figure 14a are more obvious in this example.

4 Max's - 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.





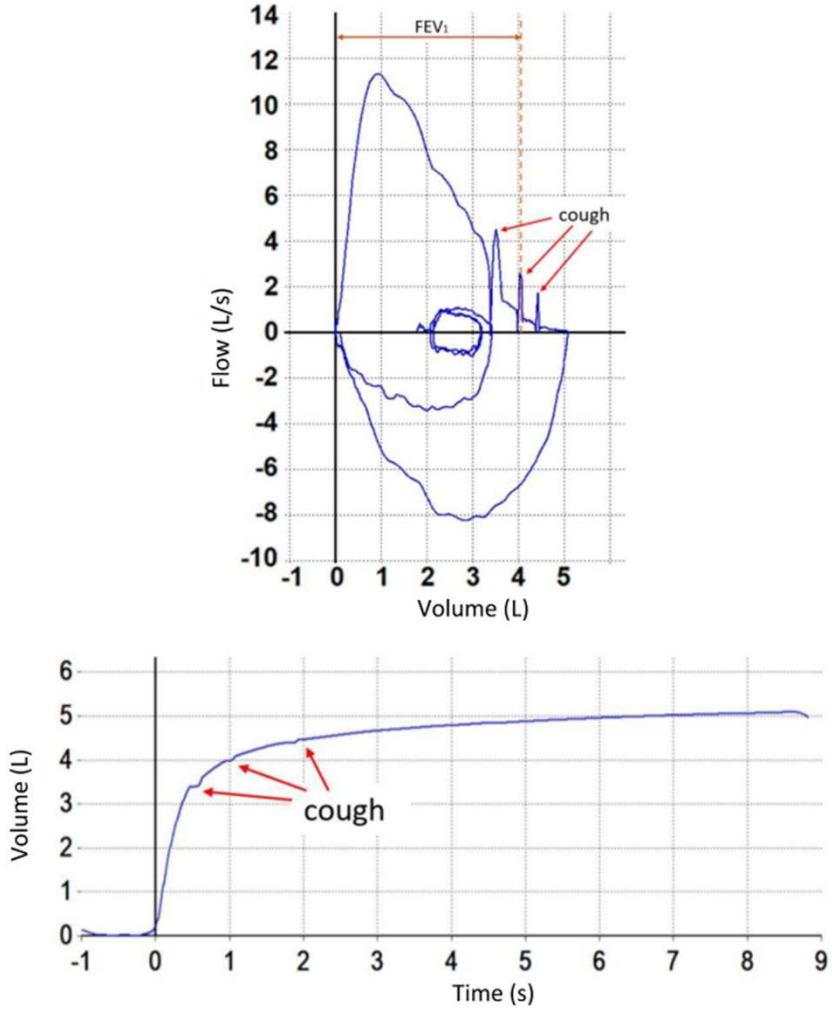


Figure E7a. A cough is seen as blips in the flow-volume graph. The volume-time graph shows that the initial cough occurred in the first second of expiration. The dashed orange line on the flow-volume graph is at the point of FEV_1 on the volume axis and more clearly shows that the initial cough occurred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

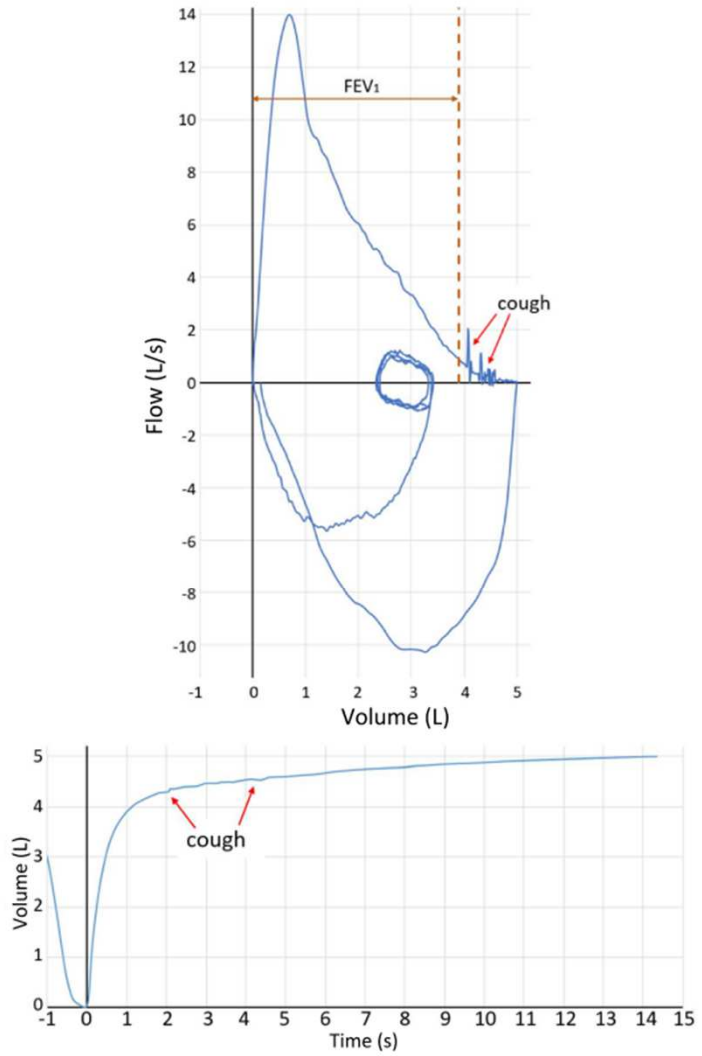
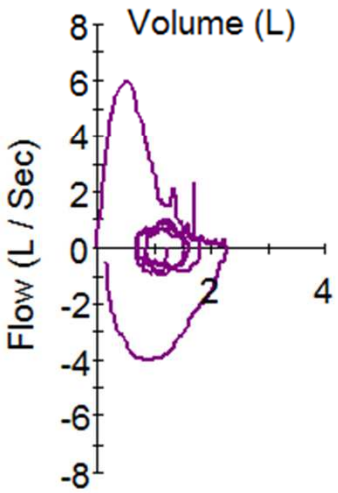


Figure E7b. A cough later in expiration. In this example, the volume-time graph does not clearly indicate the start of the cough. The dashed orange line at FEV_1 on the flow-volume graph shows that the cough occurred later than 1 s and thus the FEV_1 and FVC measurements are acceptable.

07:47:22



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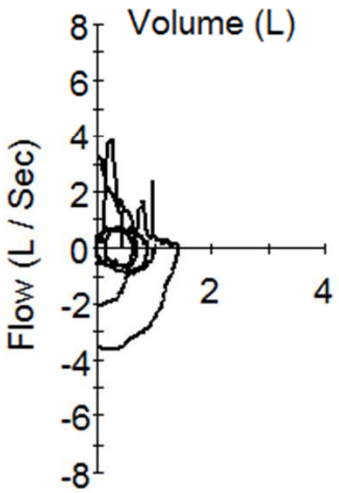

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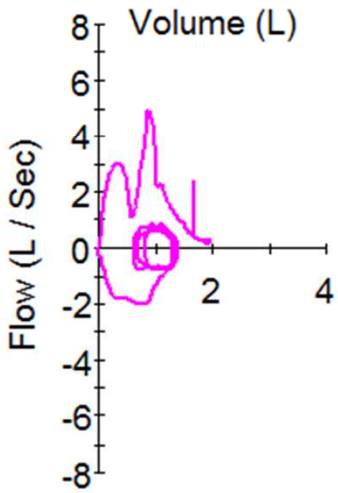

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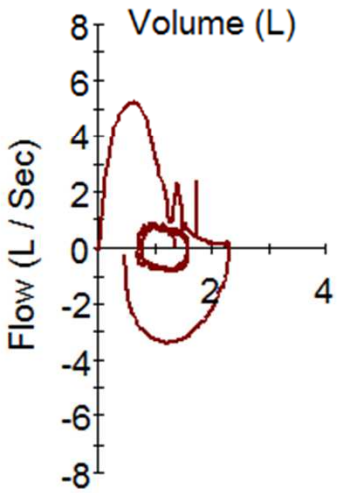
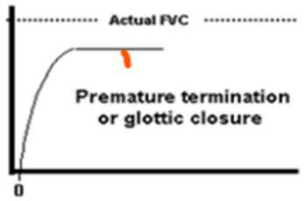


Within-Maneuver Acceptability: No Glottic closure in the first second of expiration

- **Must have no glottic closure in the first second of expiration***
  - Yes, required for both Acceptability and Usability for both 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.



4 Max's - Within-Maneuver Acceptability: EOFE / FVC

- Continuing from FEV1
- Continuing to
  - EOFE
    - Plateau
    - Time
    - Repeatability
  - Maximal expiration level

Within-Maneuver Acceptability: No Glottic closure after first second of expiration

- **Must have no glottic closure after 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.

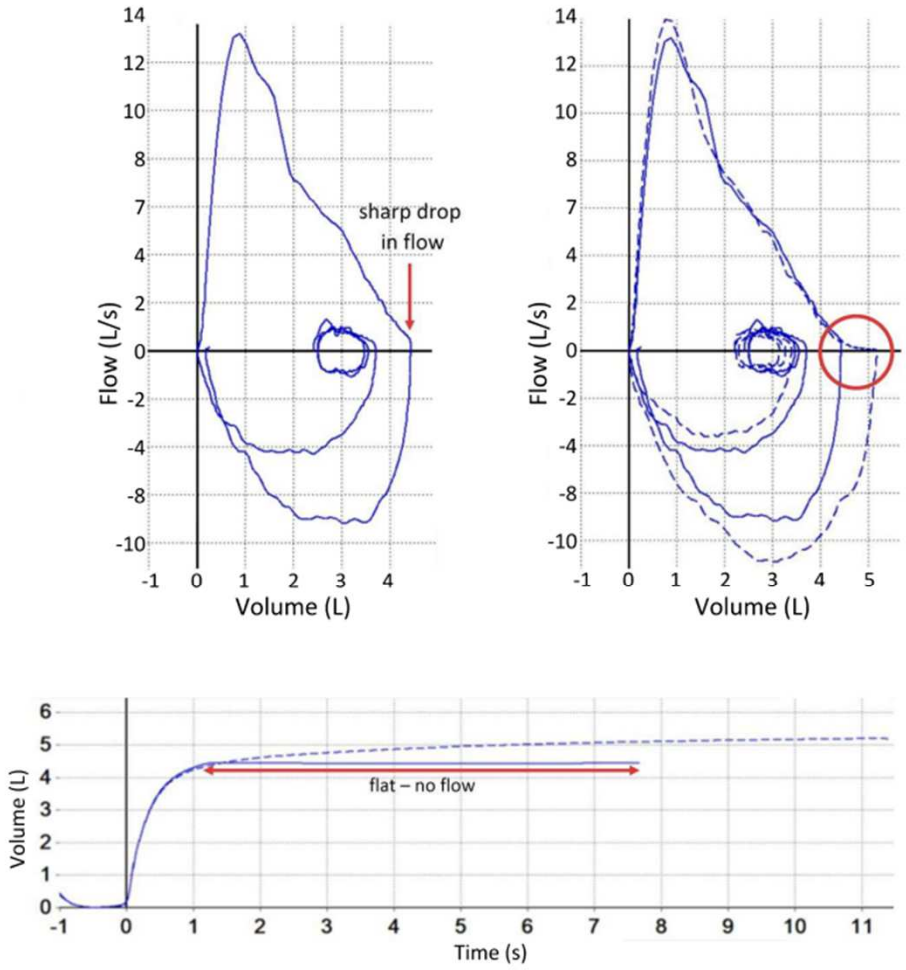


Figure E9. Glottis closure: note the sudden drop in flow in the flow-volume graph and the flat line after 1.25 seconds in the volume-time graph. Compare the glottis closure (solid line - FVC = 4.4 L) to an acceptable maneuver (dashed line - FVC = 5.2 L) in the same subject. In both cases, FEV_1 = 4.3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

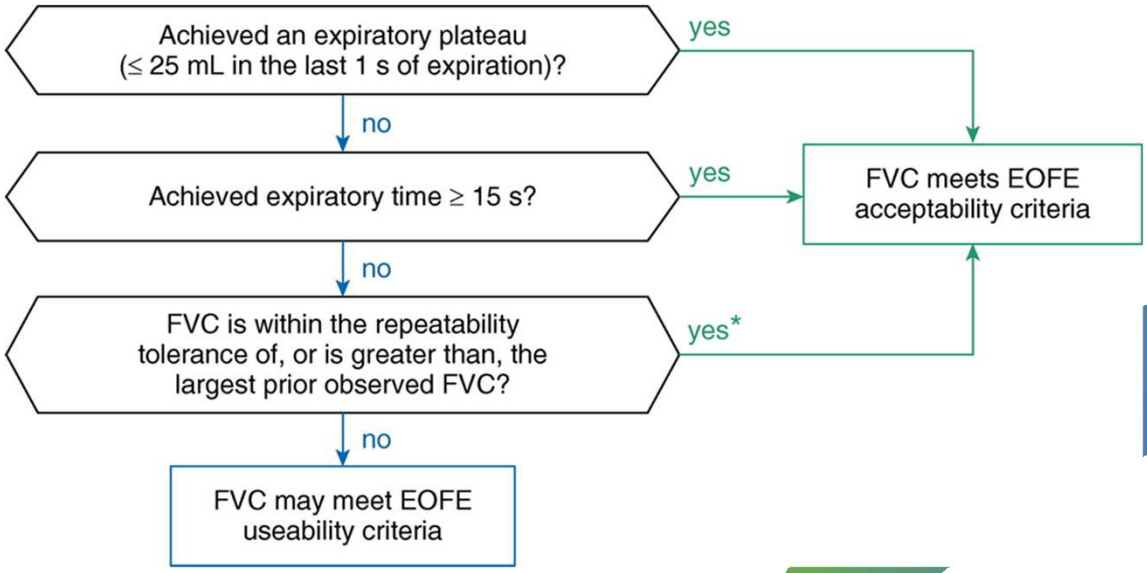
Plateau

- < 0.025 L/sec change
- > 1 second

Forced exhalation **time**

- > 15 seconds

FVC meets **repeatability** criteria

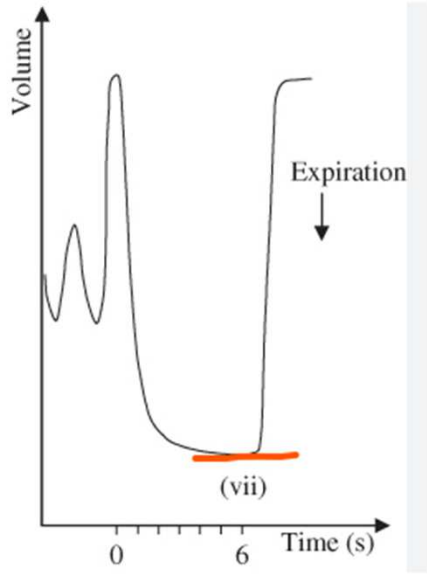


Within-Maneuver Acceptability: End Of Forced Exhalation – EOFE

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

Must achieve <u>one</u> of these <u>three</u> EOFE indicators:

- No, not required for neither Acceptability nor Usability for FEV1
- Yes, required for <u>Acceptability</u> for FVC
- No, not required for <u>Usability</u> for FVC



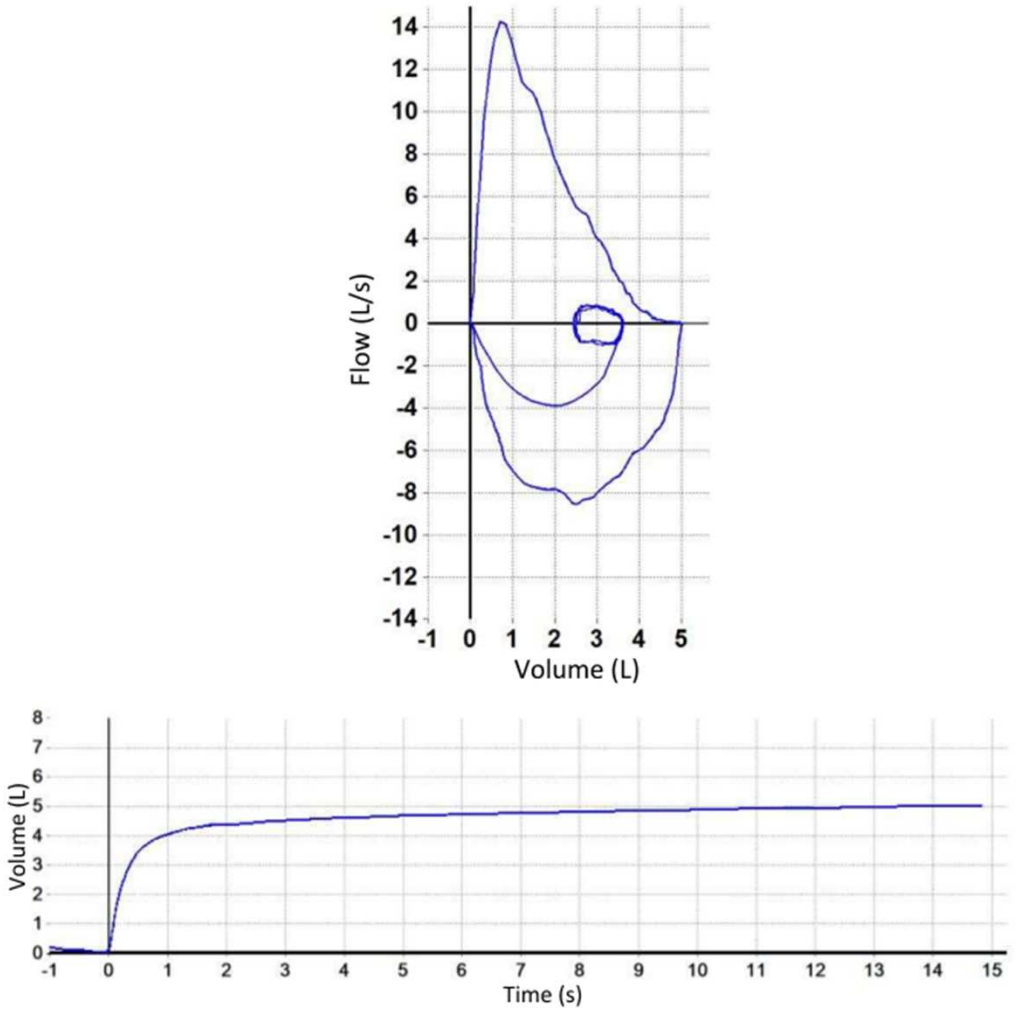


Figure E1. An acceptable maximal maneuver by a normal male (age 68.4 yr). The flow-volume graph has a fast start and sharp peak with a smooth drop to zero flow. There is a steep slope at the start of the volume-time curve with a plateau at the end of expiration. *(reproduced with permission – RESPTREC™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

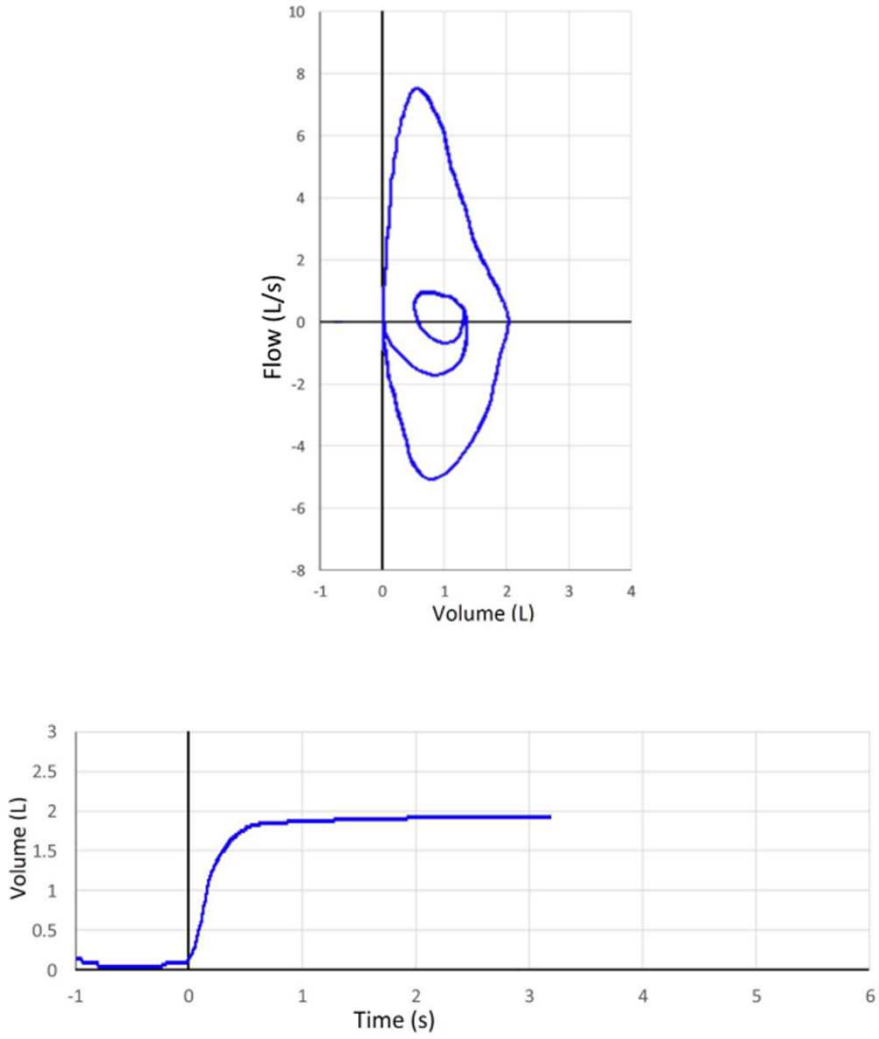


Figure E4. An acceptable maximal maneuver by a male (age 77.3 yr) with restrictive lung disease. Note that a plateau was reached in less than 3 s of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

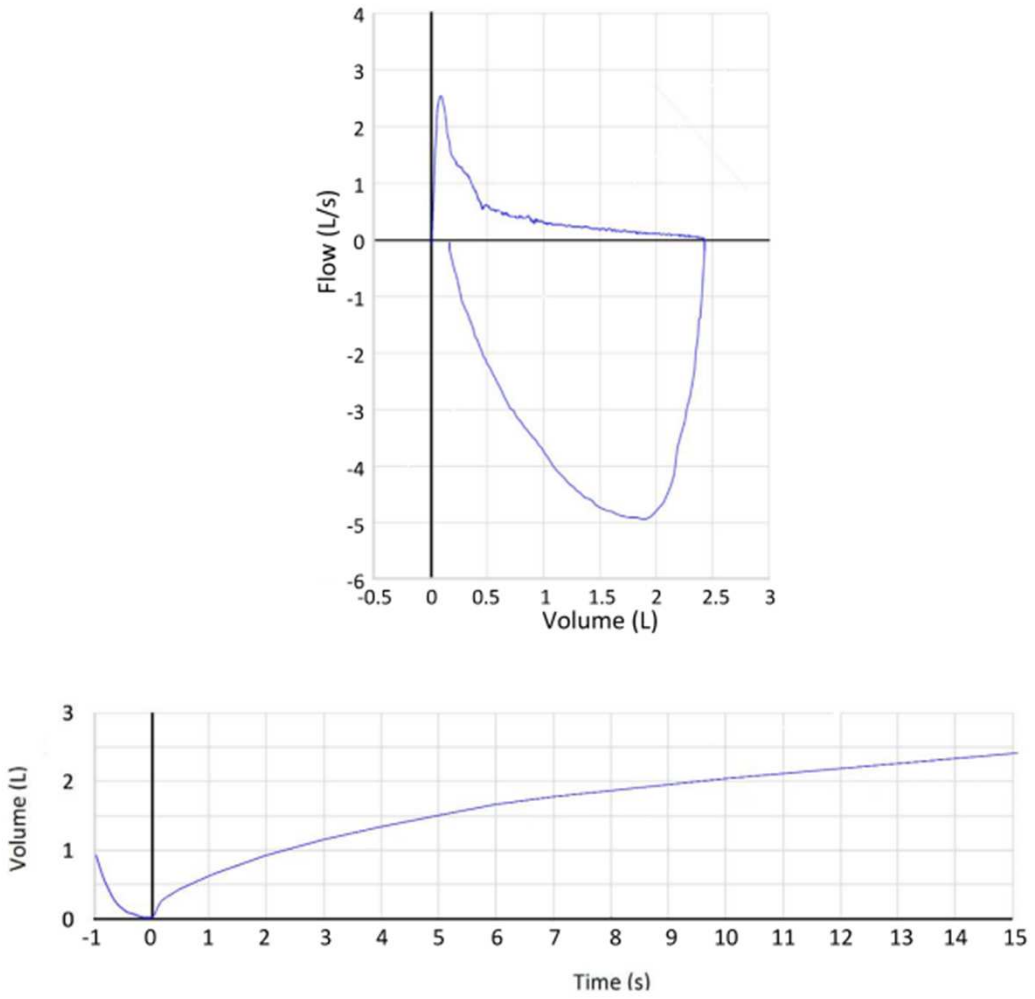


Figure E3. An acceptable maximal maneuver by a female (age 52.6) yr with very severe obstruction. Note that no plateau was reached by 15 s of expiration. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*

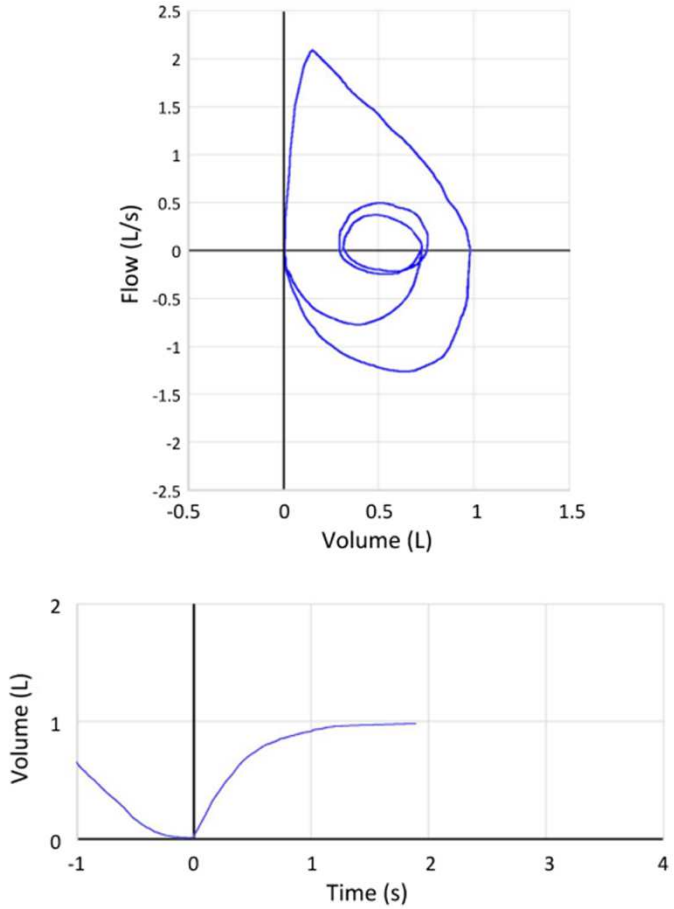


Figure E2. An acceptable maximal maneuver by a normal male (age 4.0 yr). Note the convex shape of the forced expiratory flow segment of the flow-volume curve which is often seen in healthy children with with high elastic recoil. Such children can empty their lungs quickly and may not be able to hold 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

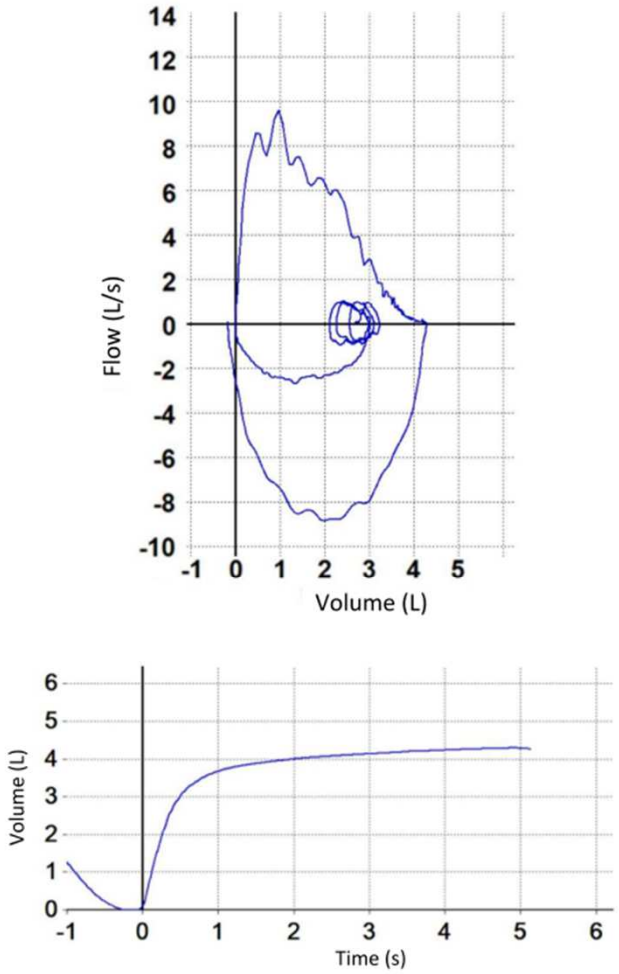


Figure E12. When the tongue obstructs the mouthpiece, there is a reduced flow and often a flutter can be seen in the flow-volume curve. The flow oscillations (sometimes referred to as sawtoothing) seen in this flow-volume curve may also be seen in cases of upper or central airway obstruction. *(reproduced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

Within-Maneuver Acceptability: Leak

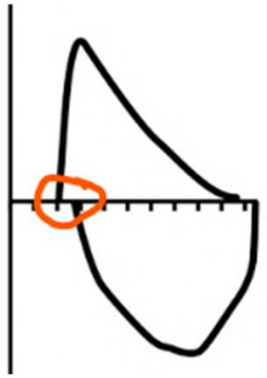
- **Must have no evidence of a leak**
  - Yes, required for Acceptability for both FEV1 & FVC
  - No, not required for Usability for neither FEV1 nor FVC
- flange-type mouthpiece
  - or assistance from the operator

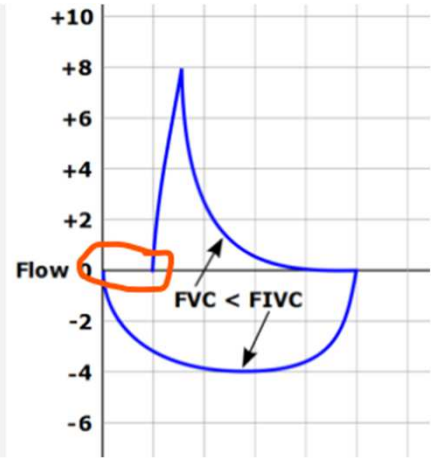
4 Max's - Within-Maneuver Acceptability: FIVC

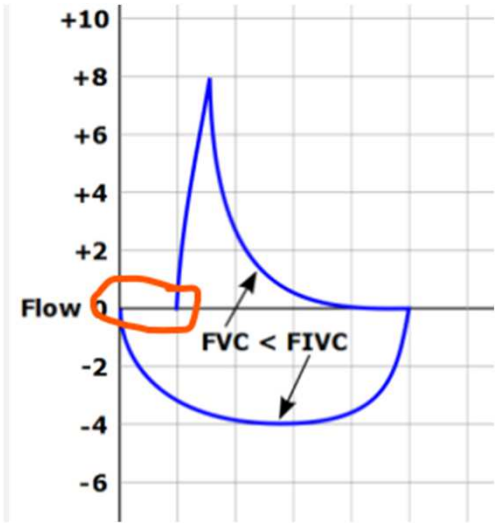
- Returning from
  - EOFE
  - FVC
  - Maximum expiration level
- Returning to
  - Maximum inspiration level
  - TLC
- Maximum Volume
- Maximum Rate ?

Within-Maneuver Acceptability: 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

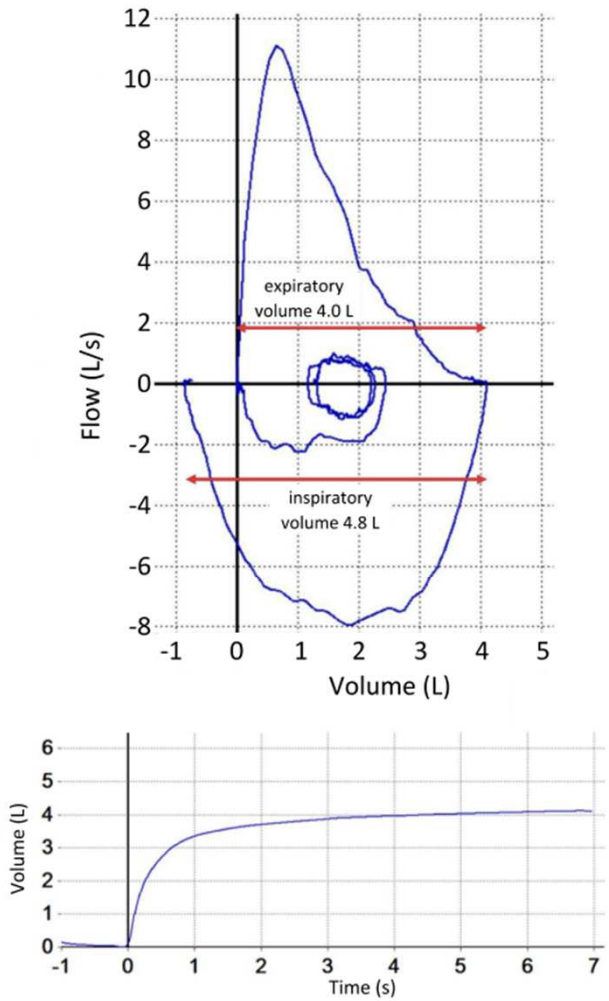
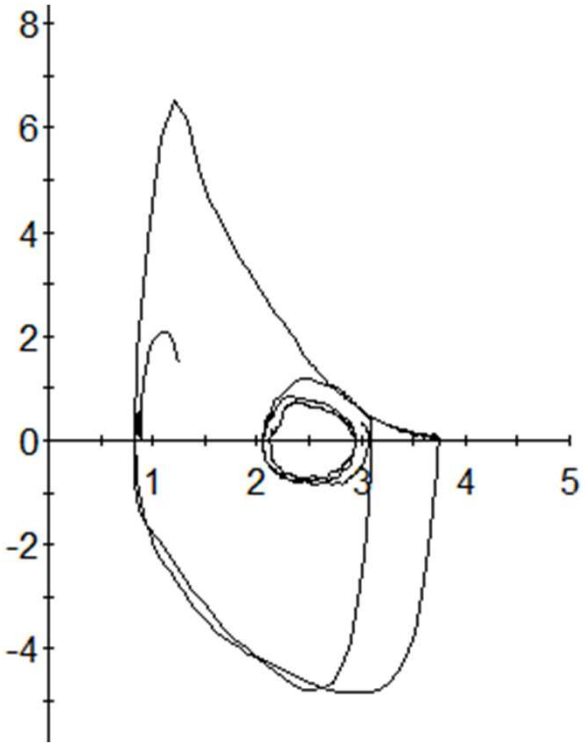


Figure E10. When the inspiratory volume at the end of the maneuver exceeds the forced expiratory volume, the subject did not reach total lung capacity before blowing out. The maneuver is not acceptable if the inspiratory volume exceeds the FVC by more than 0.100 L or 5% of FVC, whichever is greater. In this example, neither FEV_1 nor FVC is acceptable. *(reproduced with permission – RESPTREC™ Spirometry Training Course, Lung Association of Saskatchewan, www.resptrec.org)*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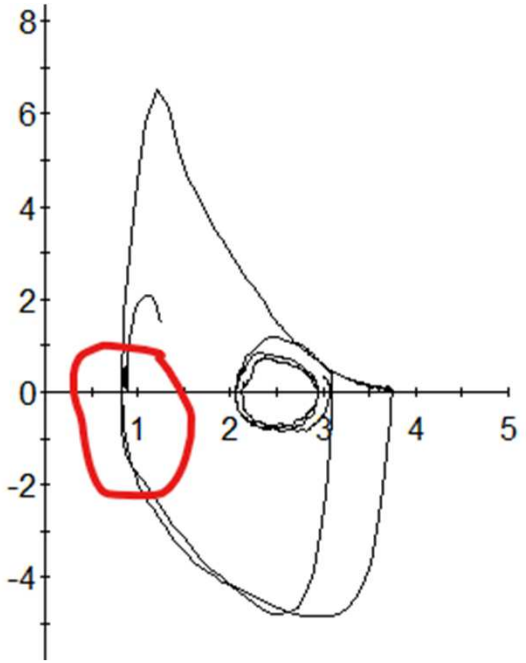
8
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5

Learning Objectives

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

- **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

(Old Term: Reproducibility)

Repeatability criteria (applied to acceptable FVC and FEV_1 values)
Age >6 yr: The difference between the two largest FVC values must be ≤0.150 L, and the difference between the two largest FEV_1 values must be ≤0.150 L
Age ≤6 yr: 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 FEV_1 values must be ≤0.100 L or 10% of the highest value, whichever is greater

Application of Acceptability and Repeatability Criteria

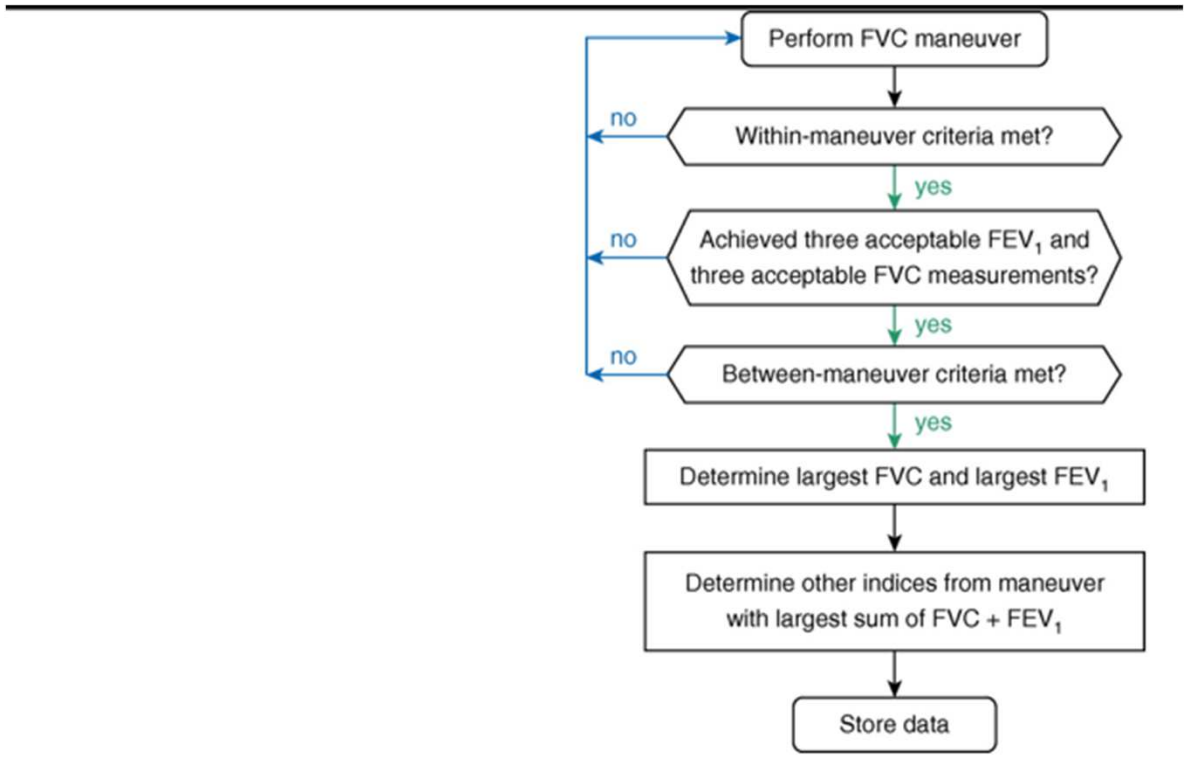


Figure 3. Flowchart outlining application of acceptability and repeatability criteria.

Am J Respir Crit Care Med, 2019

Learning Objectives

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

- **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.

Grading System for FEV1 & FVC

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

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…

- **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:
  - Back Extrapolated Volume (BEV) exceeds limit
- Instruction to Patient:
  - **“Blast out immediately when completely full”**

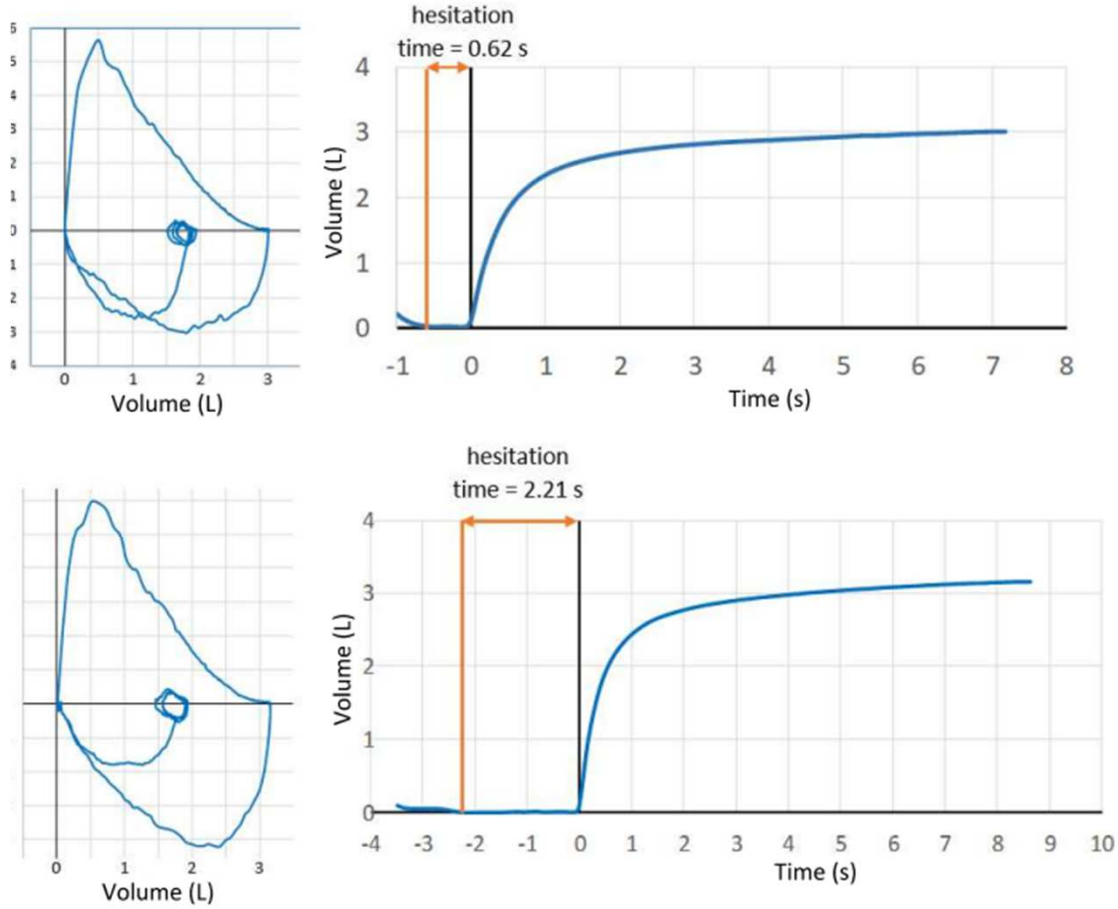
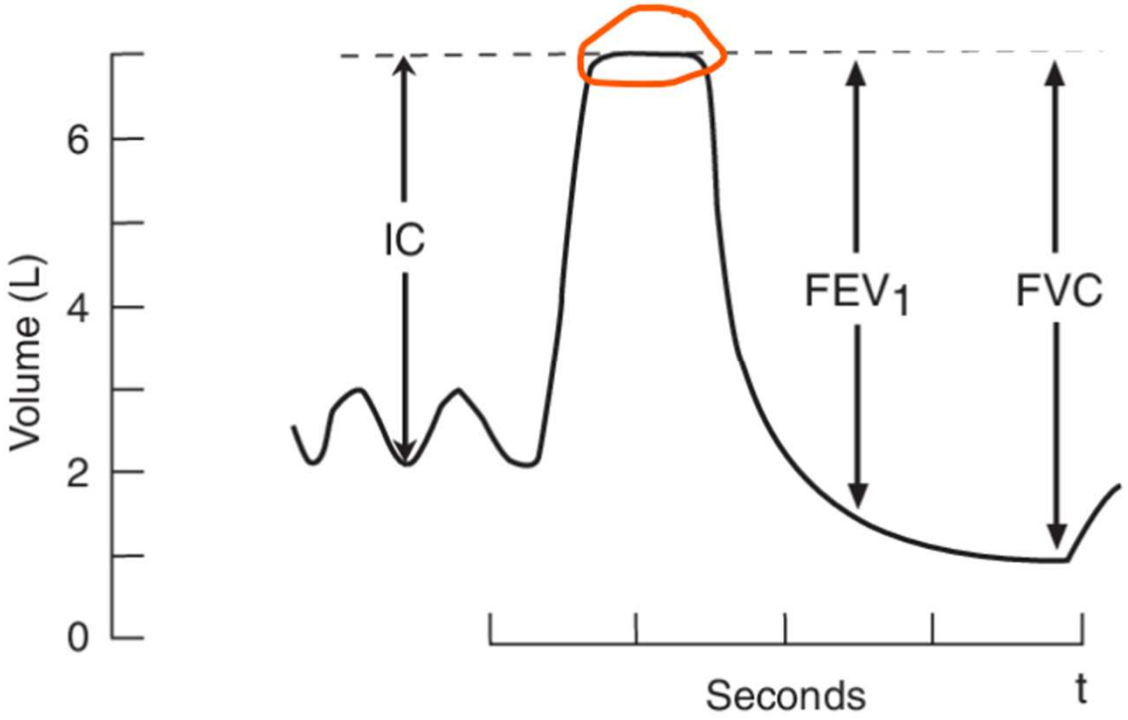
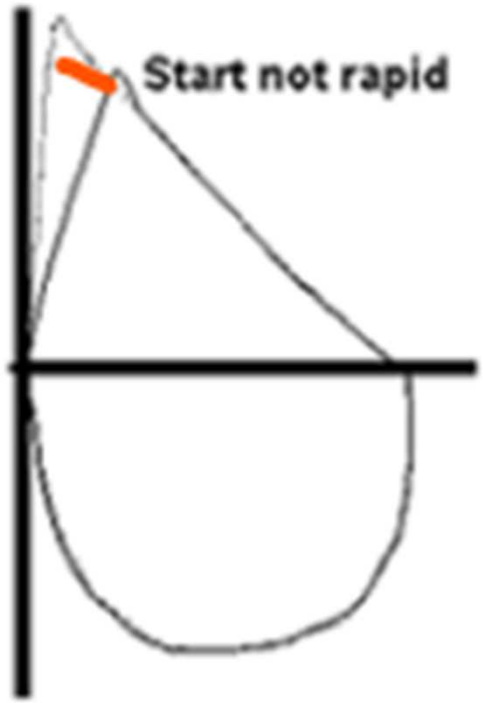


Figure E13. Hesitation time is defined as the time from attaining maximum inspired lung volume to the back-extrapolated time zero which should be less than 2 s. The upper panel shows an acceptable maneuver with a hesitation time of 0.62 s. The lower panel shows a maneuver from the same person but with 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.


Volume (L)
6
4
2
0
IC
FEV1
FVC
Seconds
t

System Warning: Slow Start

- Warning Trigger:
  - Rise Time > 150 ms
  - Peak shifted to the right
- Instruction to Patient:
  - **“Blast out immediately when completely full”**



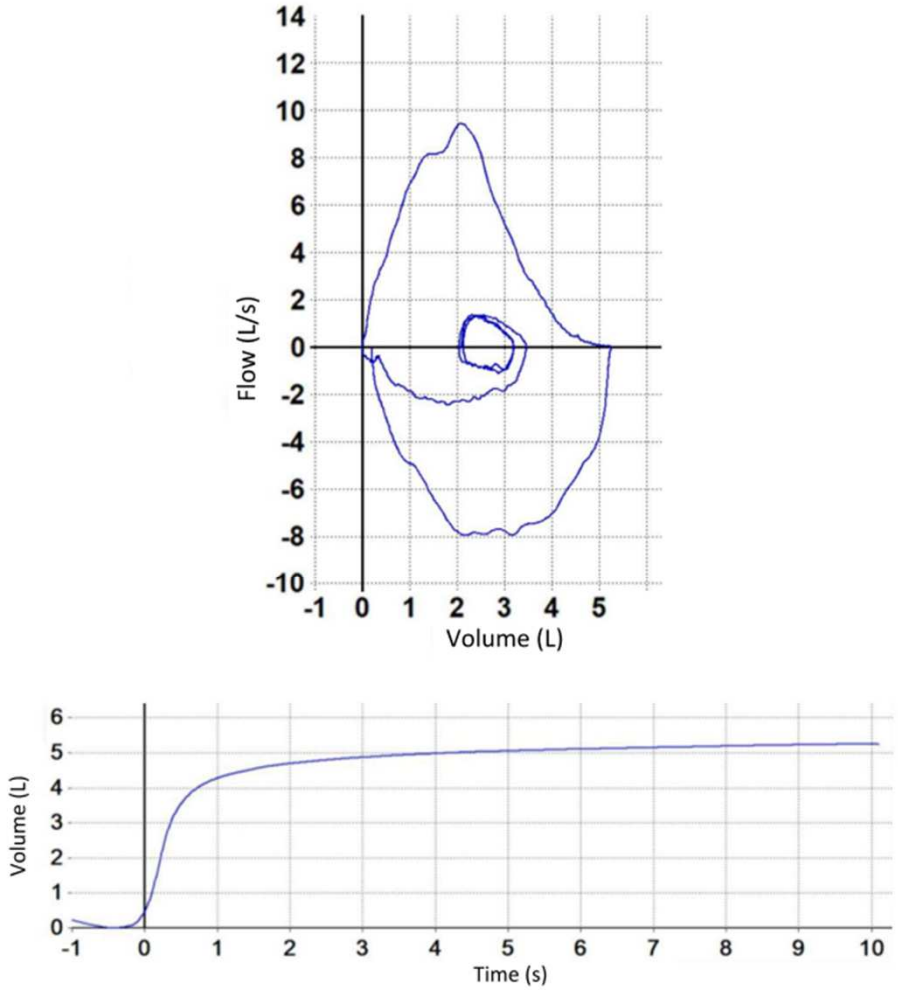


Figure E11. When a subject has a slow start to expiration, the flow-volume curve may still show a peak but it occurs later in expiration. In this example, the rise time from 10% to 90% of peak flow is 320 ms, well in excess the 150 ms recommendation. *(reproduced with permission – RESPTREC™ Spirometry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

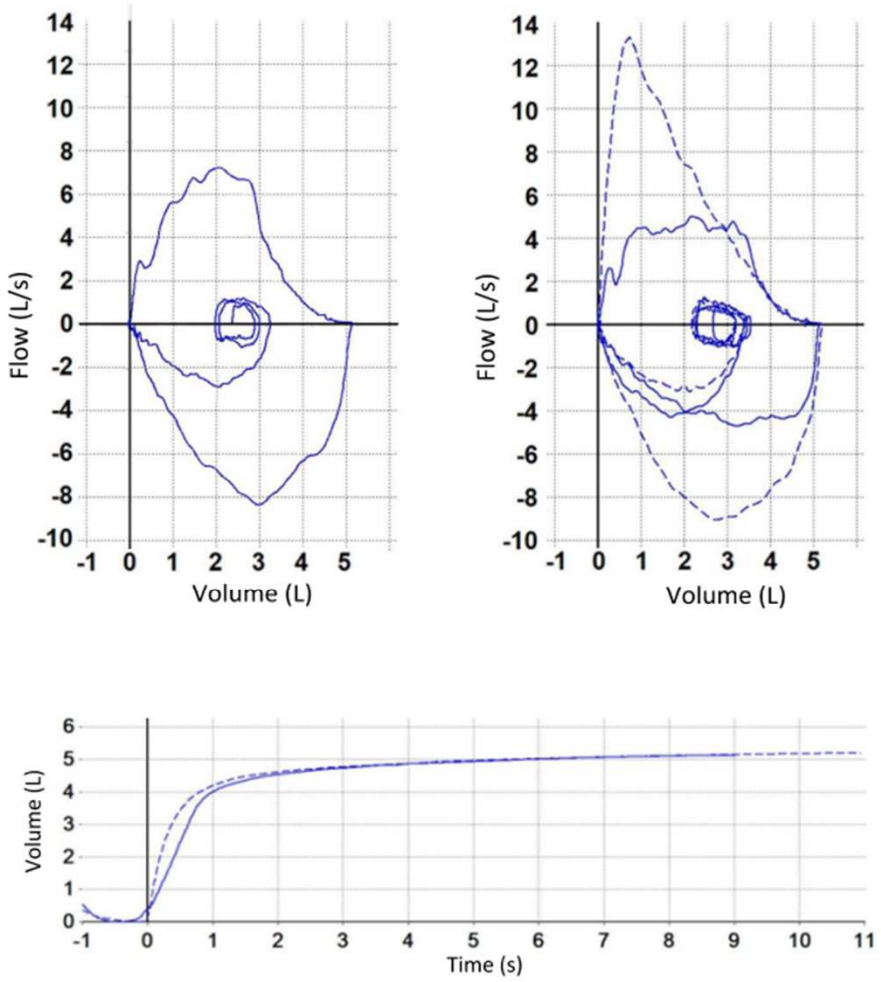
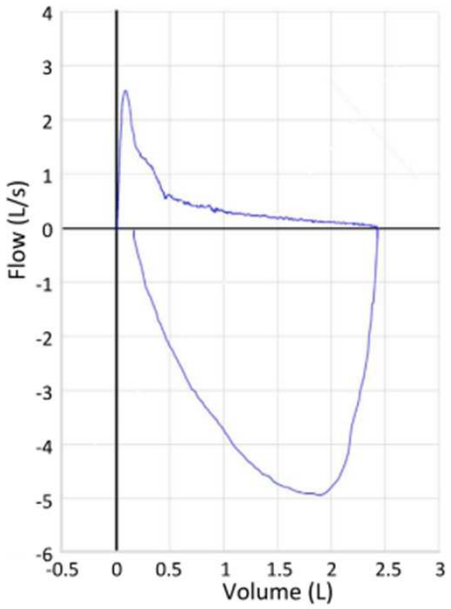


Figure E6. A sub-maximal effort is characterised by a rounded flow-volume curve and a less steep slope at the start of the volume-time curve. Compare a sub-maximal effort (solid line) to an acceptable maneuver (dashed line) in the same subject. A sub-maximal effort will often have a rise time >150 ms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

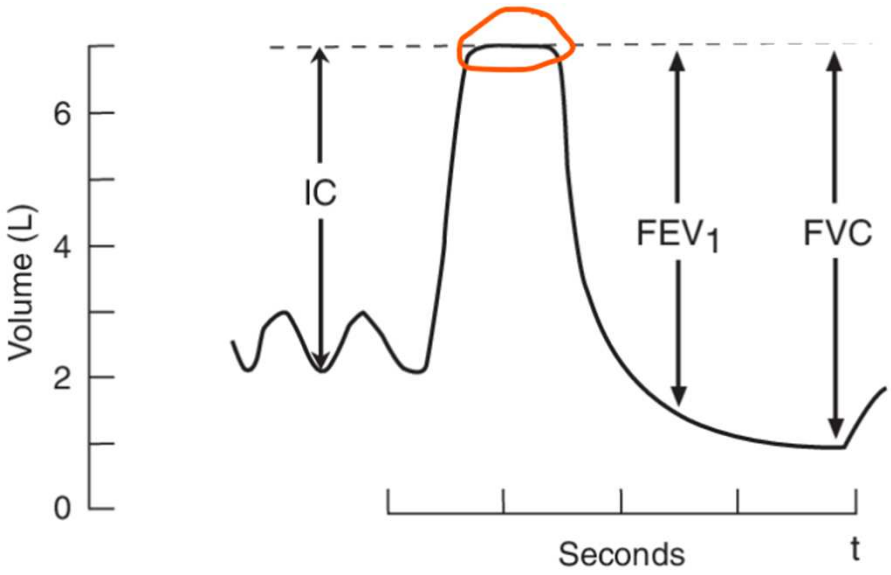


NOTE: This is acceptable because it reached > 15 secs

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)*

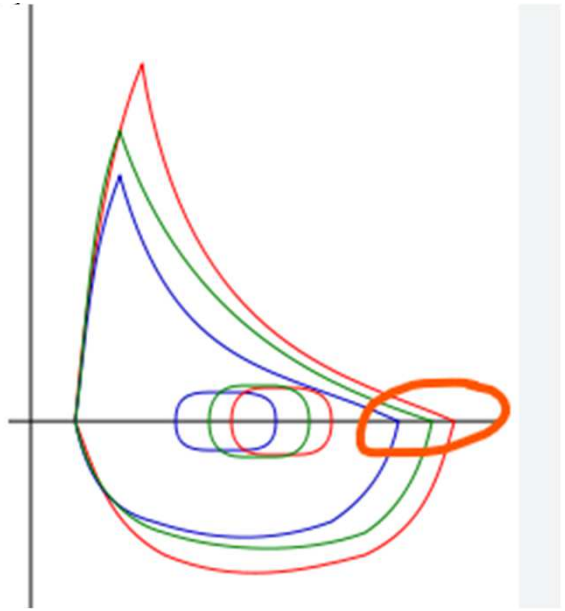
System Warning: Hesitation at Maximum Vol

- Warning Trigger:
  - Hesitation time > 2 s
- Instruction to Patient:
  - **“Blast out when completely full”**



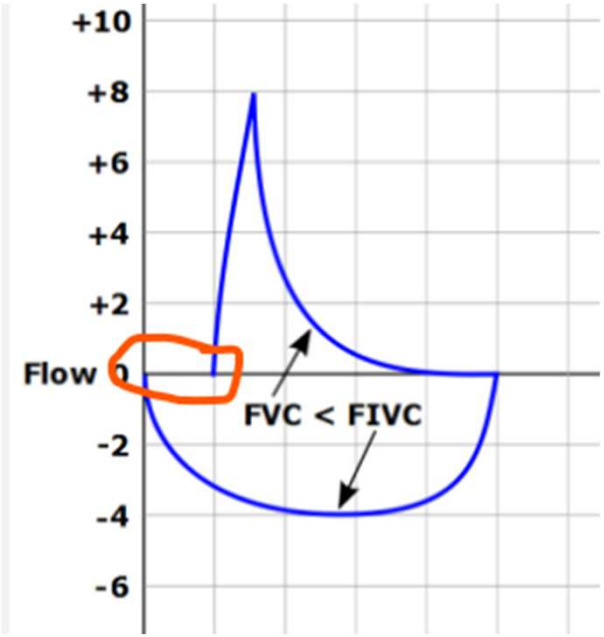
System Warning:
Low Forced Expiratory Volume

- Warning Trigger:
  - FVC less than max FVC from previous maneuvers
- Instruction to Patient:
  - **“Take the deepest breath possible and keep going until completely empty”**



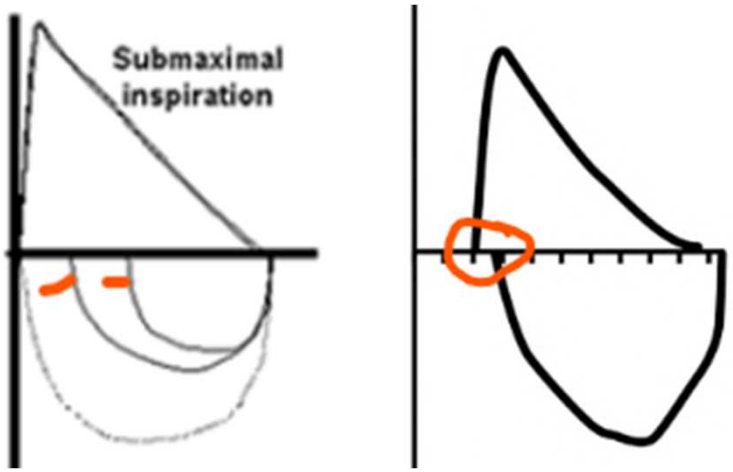
System Warning: Incomplete Inspiration Prior to FVC

- 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 < 90% FVC
- Instruction to Patient:
  - **“After completely emptying your lungs, remember to breathe in – back to the top”**

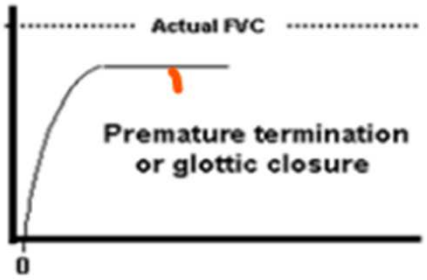


System Warning: Slow Filling

- 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

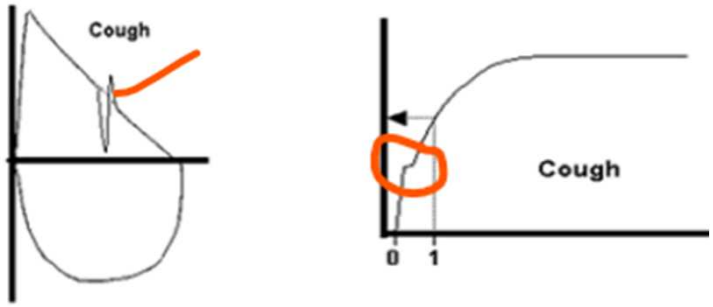
- Warning Trigger:
  - Suspected glottis closure
- Instruction to Patient:
  - **“If you feel your throat closing relax, but keep pushing”**
  - **“Maintain slight chin elevation”**



Early termination
Glottic closure

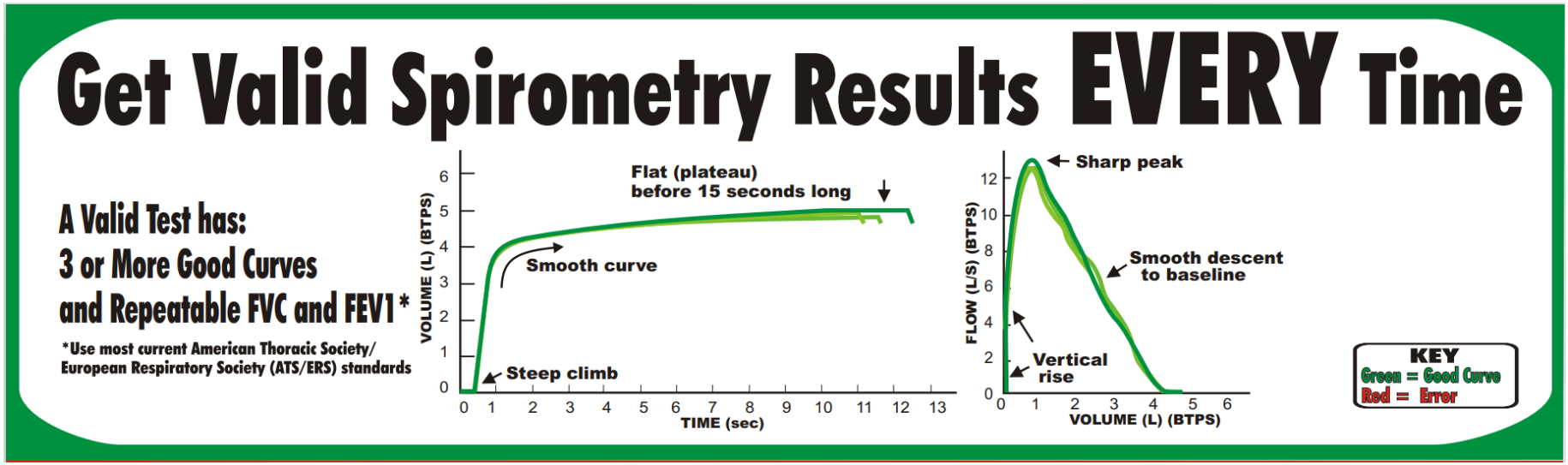
System Warning: Cough in First Second of Expiration

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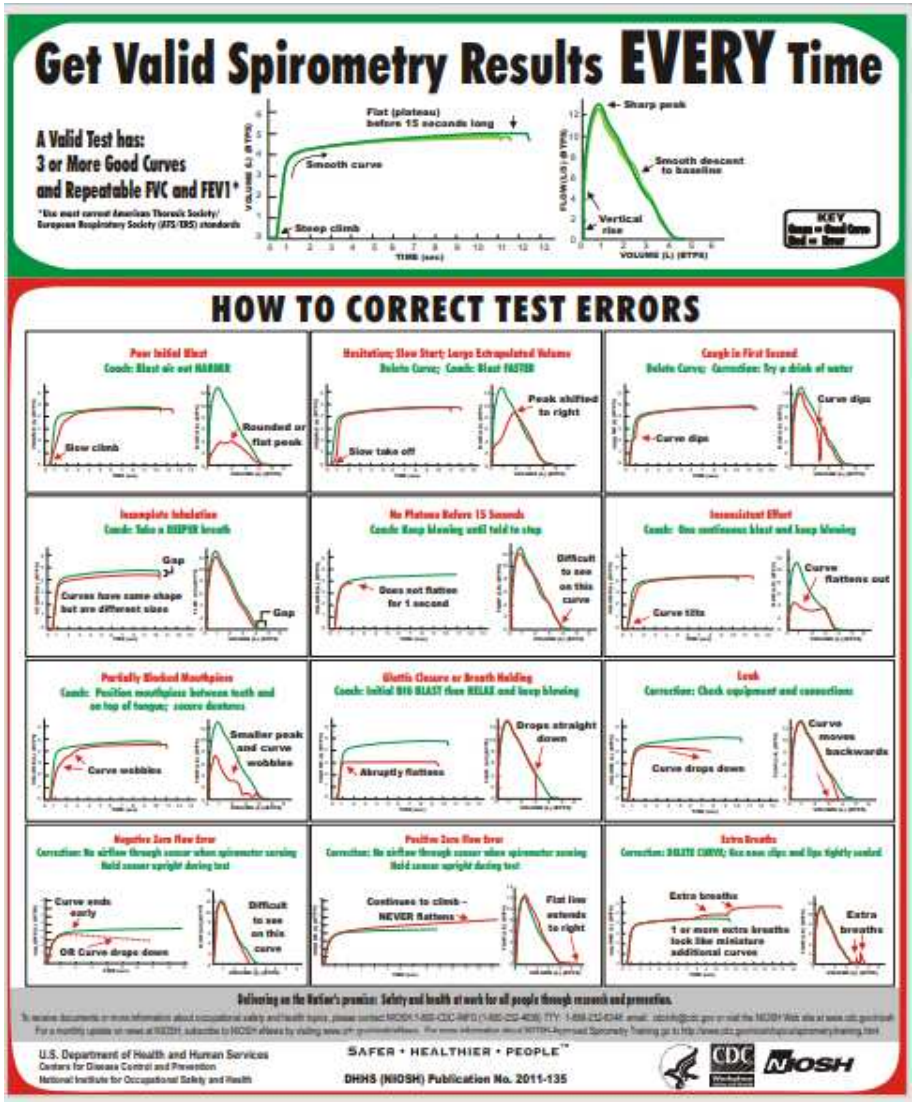
CDC - NIOSH: [DHHS (NIOSH) Publication No. 2011-135]



Poor Performance?

Ask the patient….

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

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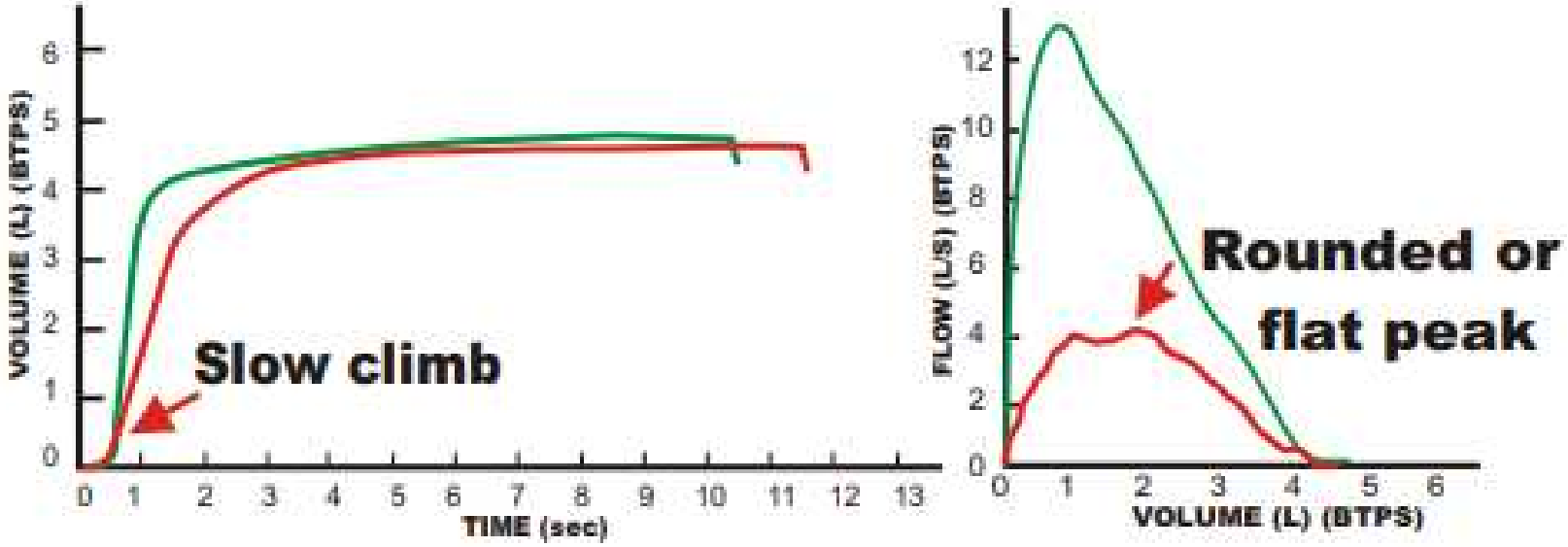
Poor Initial Blast

Coach: Blast air out HARDER



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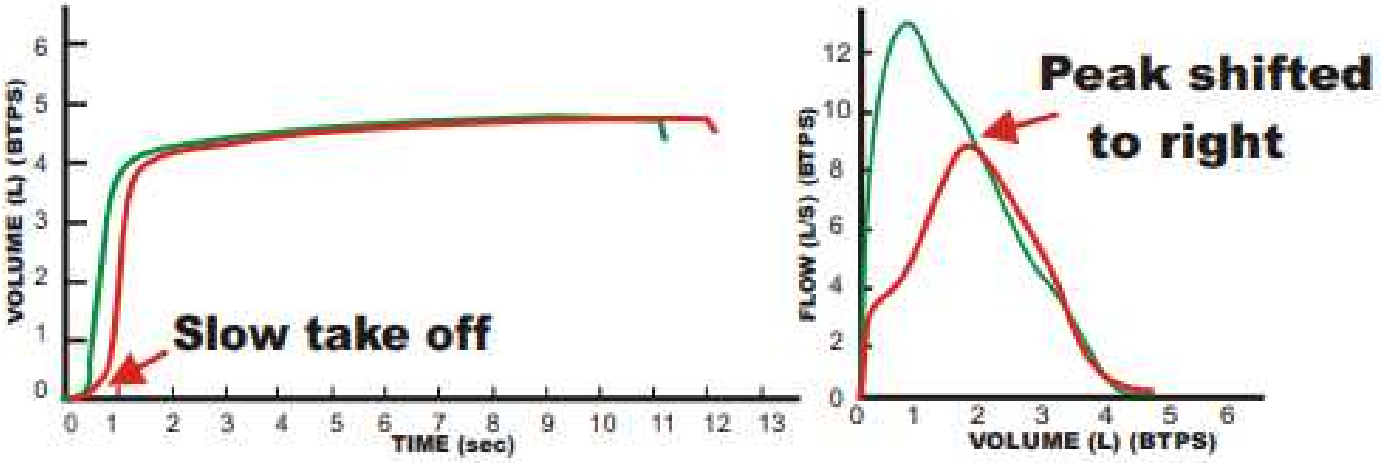
Hesitation; Slow Start; Large Extrapolated Volume

Delete Curve; Coach: Blast FASTER



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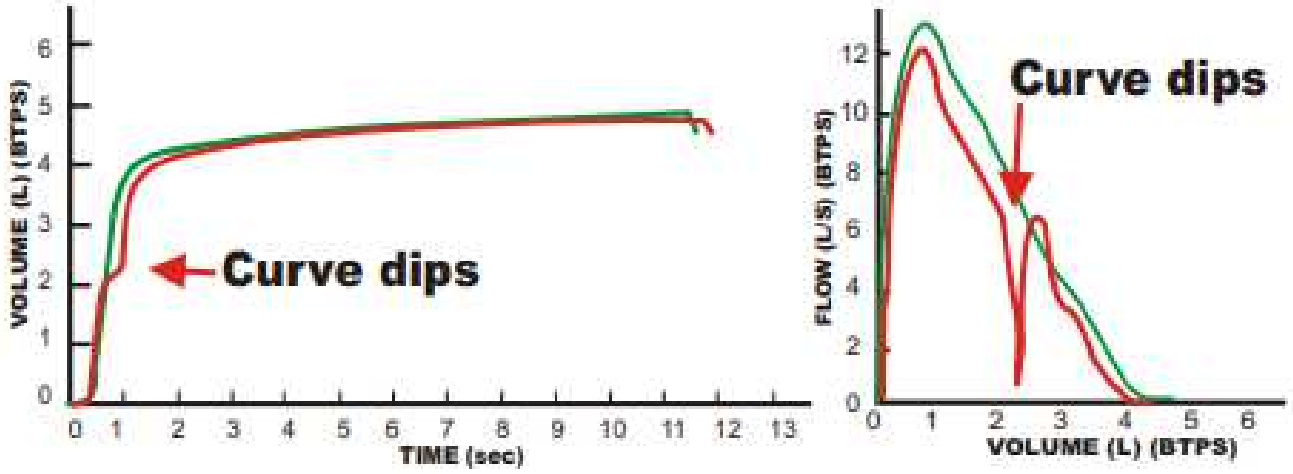
Cough in First Second

Delete Curve; Correction: Try a drink of water



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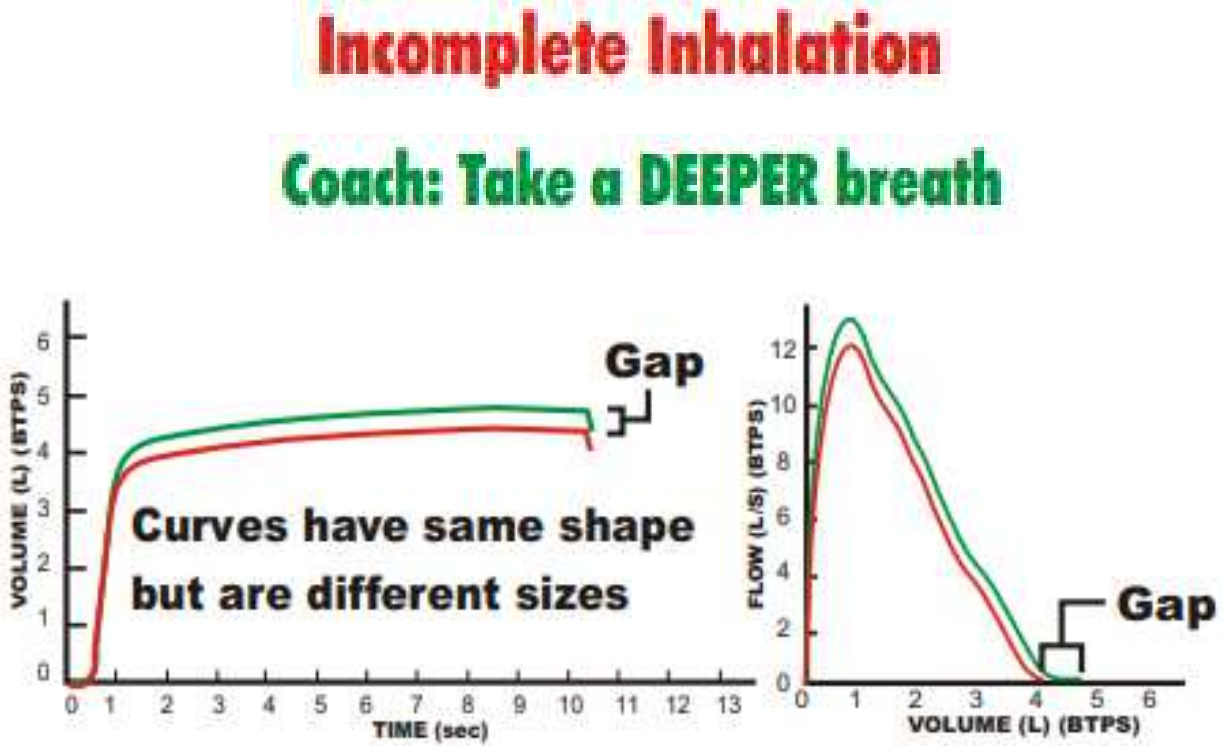
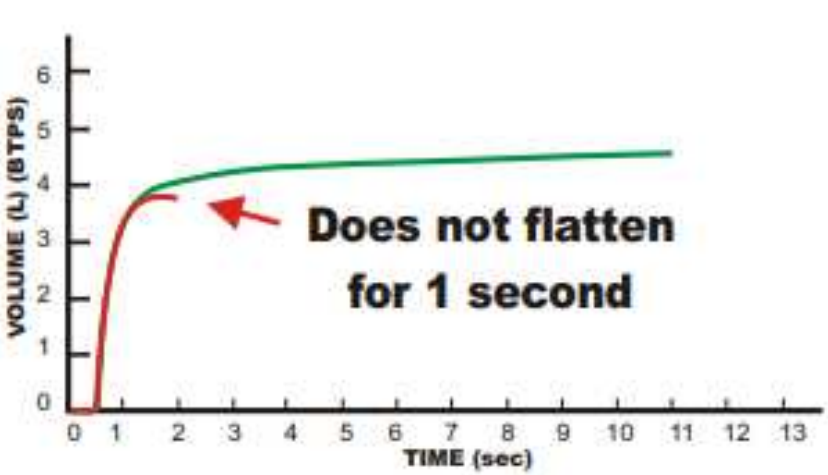
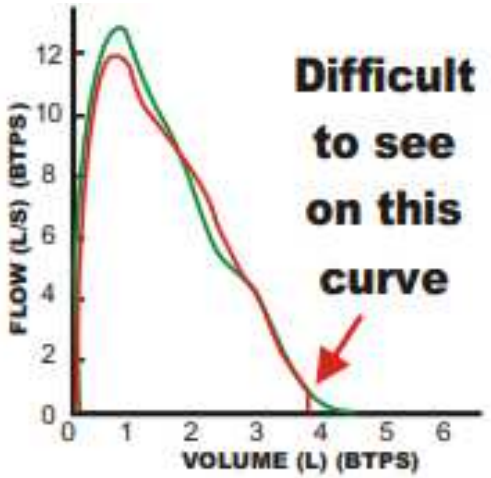


Get Valid Spirometry Results EVERY Time

No Plateau Before 15 Seconds

Coach: Keep blowing until told to stop





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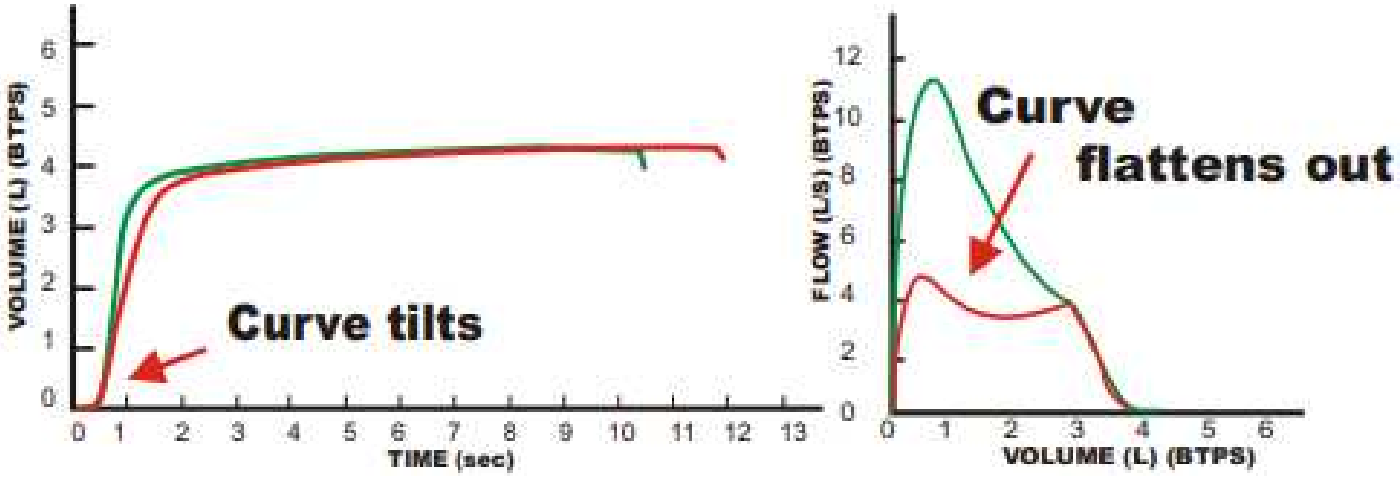
Inconsistent Effort

Coach: One continuous blast and keep blowing



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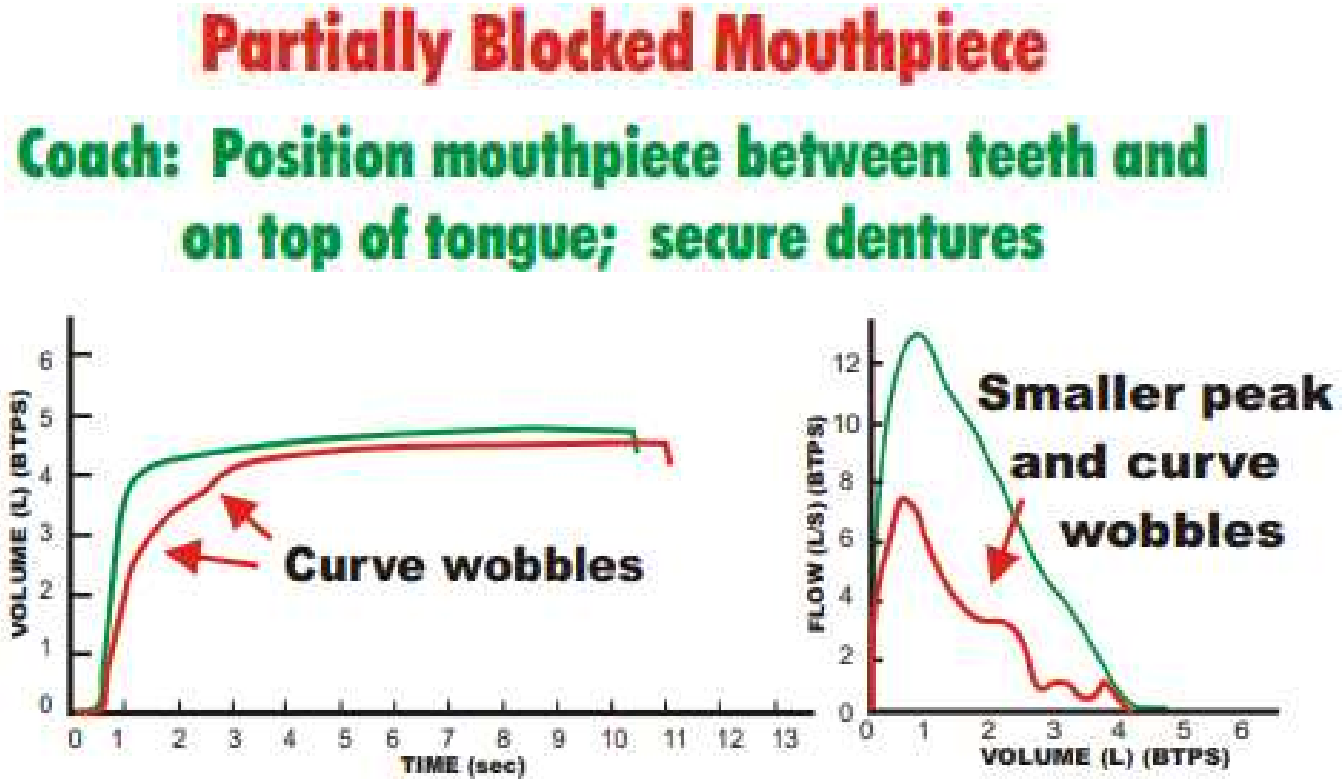
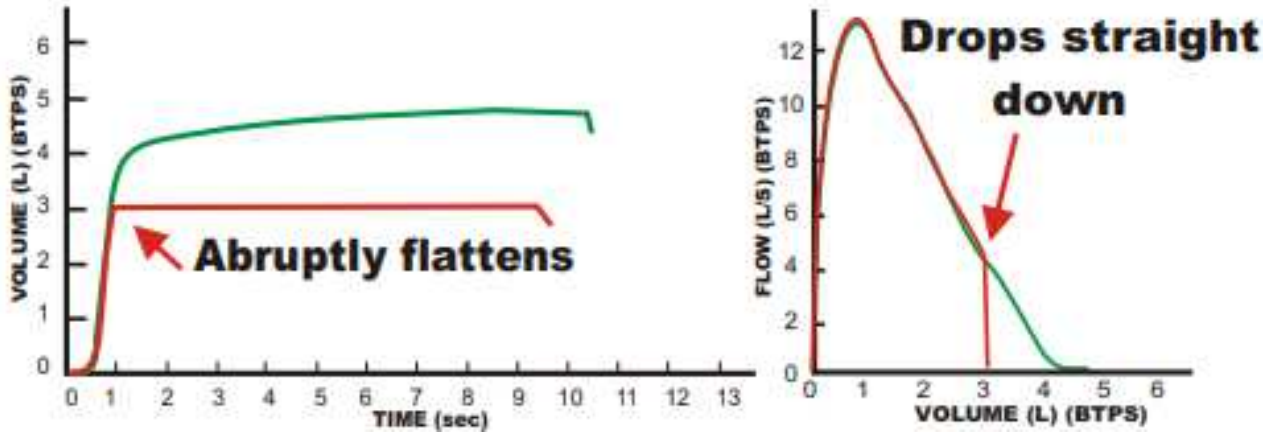


Get Valid Spirometry Results EVERY Time

Glottis Closure or Breath Holding

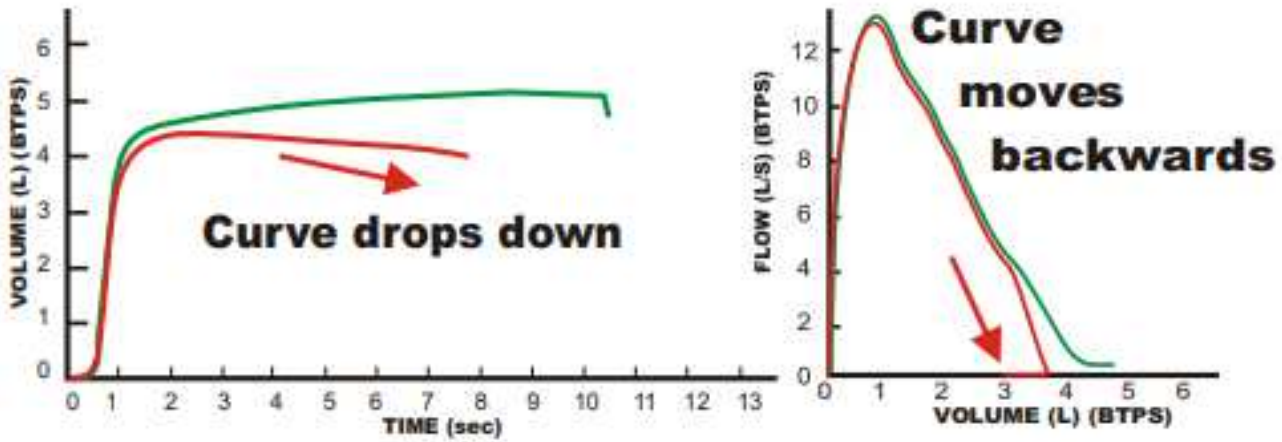
Coach: Initial BIG BLAST then RELAX and keep blowing



Get Valid Spirometry Results EVERY Time

Leak

Correction: Check equipment and connections



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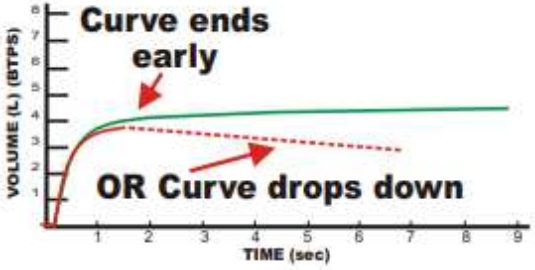
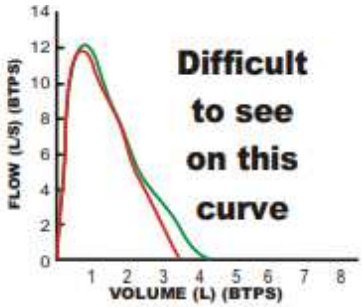
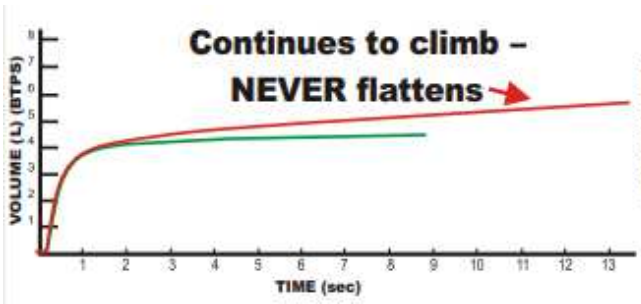
Negative Zero Flow Error

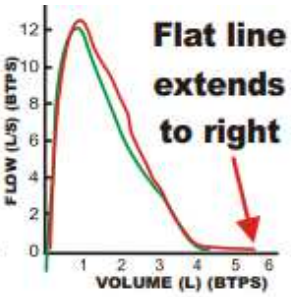
Positive Zero Flow Error

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





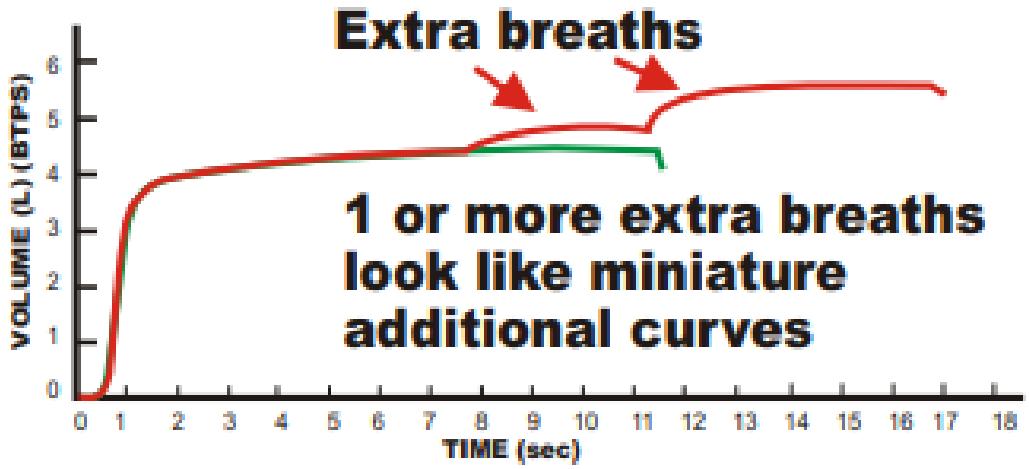


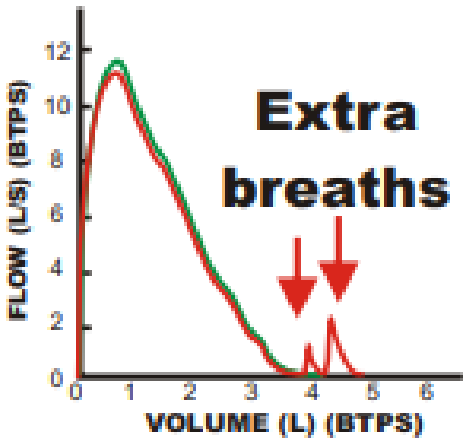


Get Valid Spirometry Results EVERY Time

Extra Breaths

Correction: DELETE CURVE; Use nose clips and lips tightly sealed

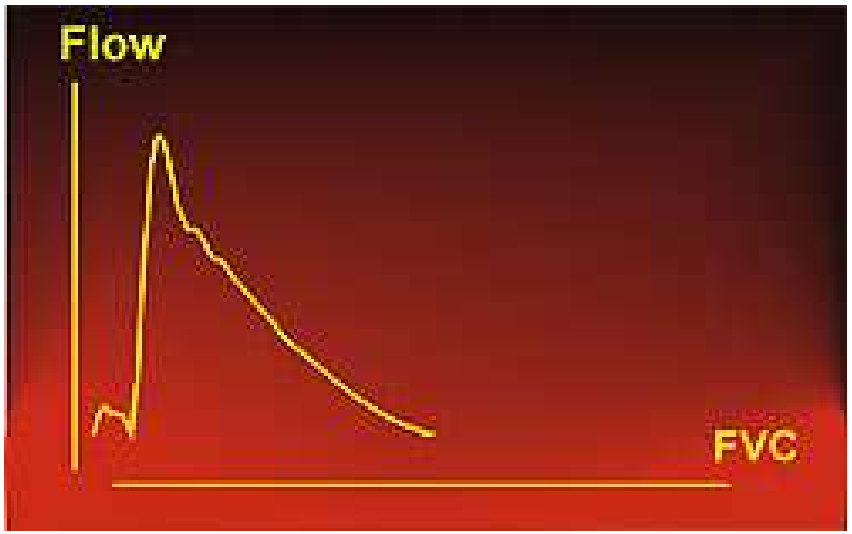




Poor Performance: Start

This subject did not blow out hard at the start of the maneuver, so that the

- first 10% of the FVC were not produced with maximal force.
- **“Blow out as hard and as completely as possible.”**
- Mouthpiece leaked?
- Patient halted?
- Data cannot be reliably interpreted.
- Shape of the curve (fairly straight descending portion) is not suggestive of expiratory airway obstruction.



Discard Submaximal Efforts

- Overlay flow–volume graphs
- Peak expiratory flow (PEF),is correlated with the pleural pressure during the maneuver,
- Decreased PEFR? Discard
  - We concluded that during standard spirometry, FEV1 is **inversely** dependent on effort. Maximal effort decreases FEV1 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.

Discard Submaximal Efforts

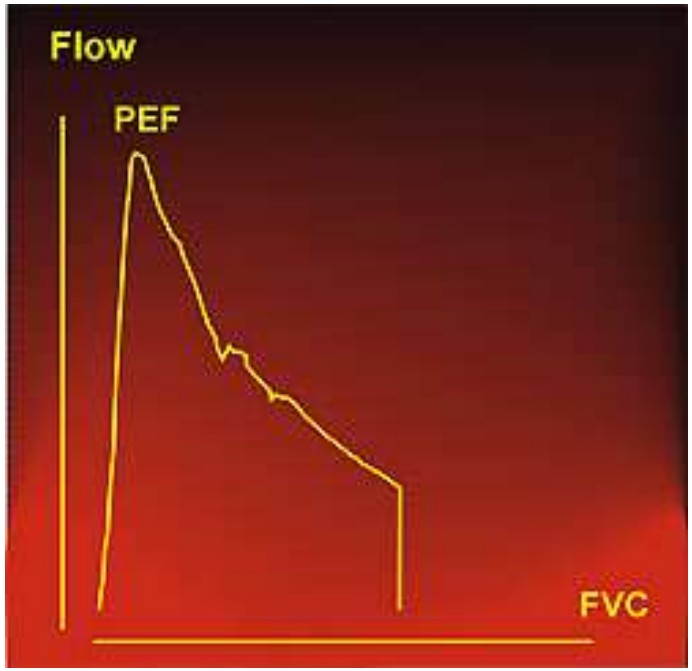
Overlay flow–volume graphs

Poor Performance: All respects

- Instruct pt to **“Exhale as forcibly and as long as possible.”**
- Encourage pt to **“Blow out as hard and as completely as possible.”**
- Neither the shape of the curve nor the data derived are suitable for interpretation.

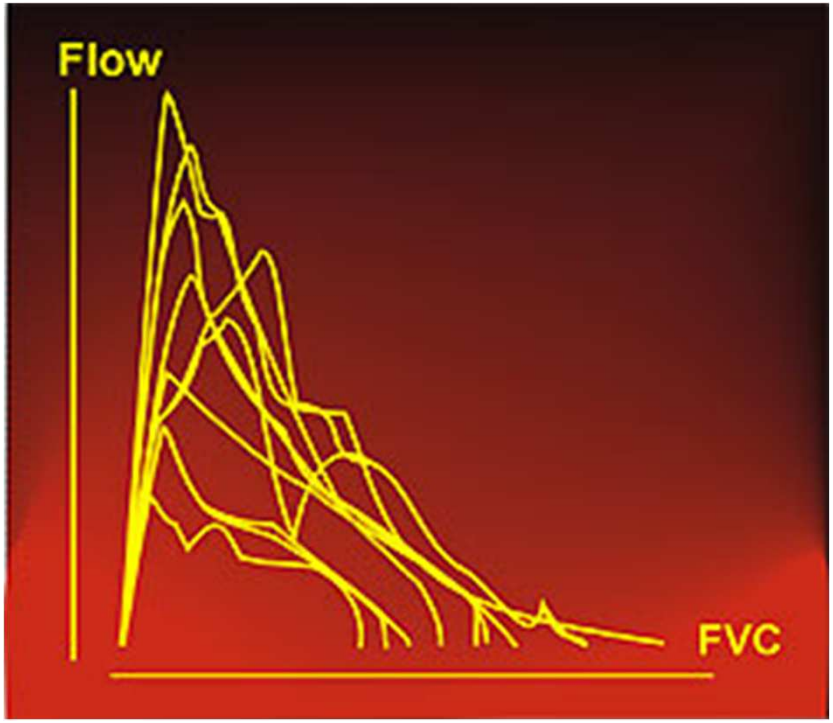
Poor Performance: Stopped Prematurely

- Forced expiratory maneuver was stopped prematurely.
- FVC underestimated,
  - as may be the FEV1.
- Data derived from such curves should NOT be interpreted.
- Judging from the straight descending portion of the curve, however, airway obstruction is unlikely in this subject.



Poor Performance:

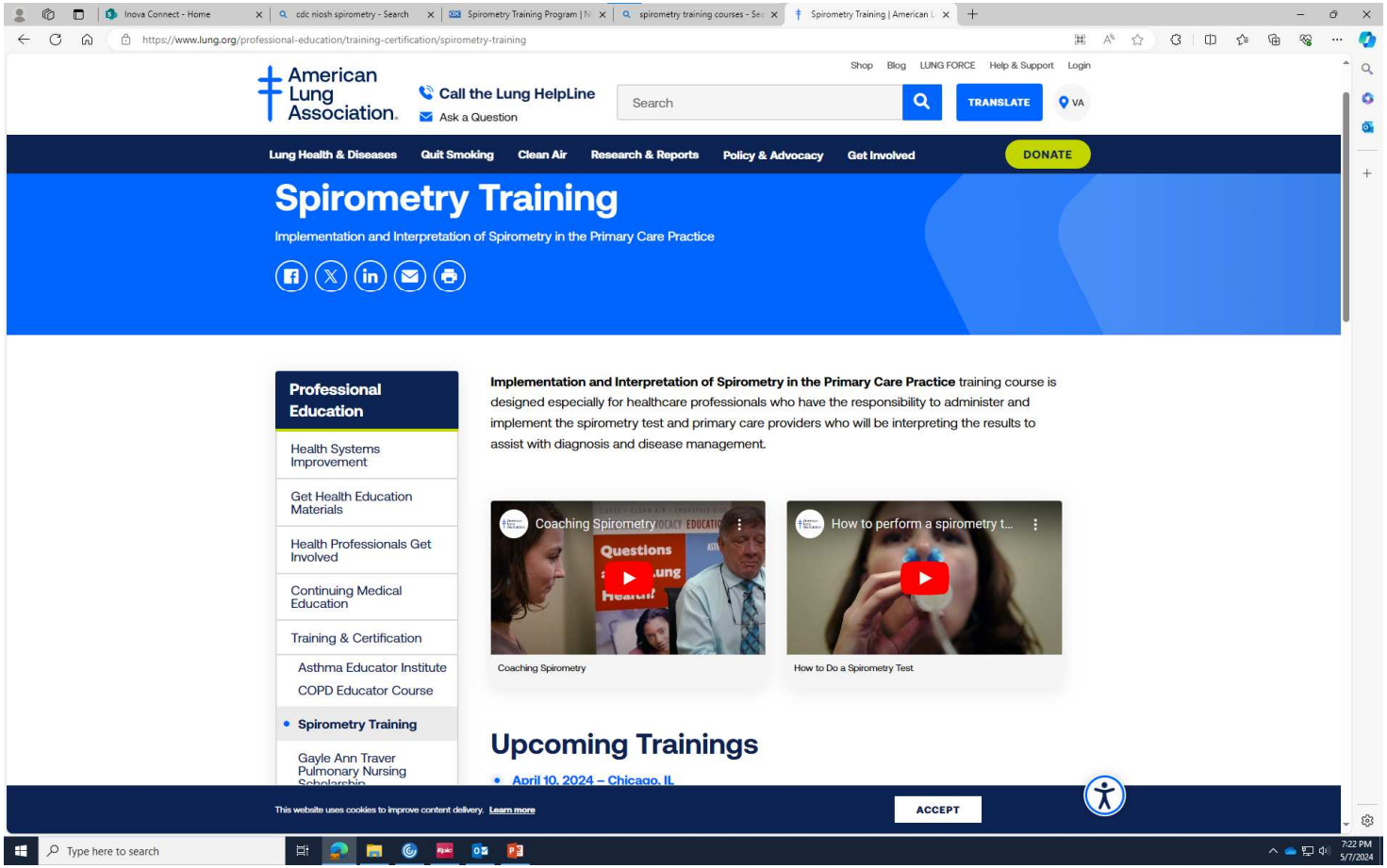
- Compliment pt *(and operator)* for patience and endurance
- Unsuccessful
- Data:
  - **<u>If</u>** the FVC or FEV1 in a **normal range**, **precludes** significant airway obstruction or a restrictive ventilatory defect.
  - If 'best' values are **below the normal** range, this should **NOT** be used as reliable evidence of lung pathology.



Spirometry Resources

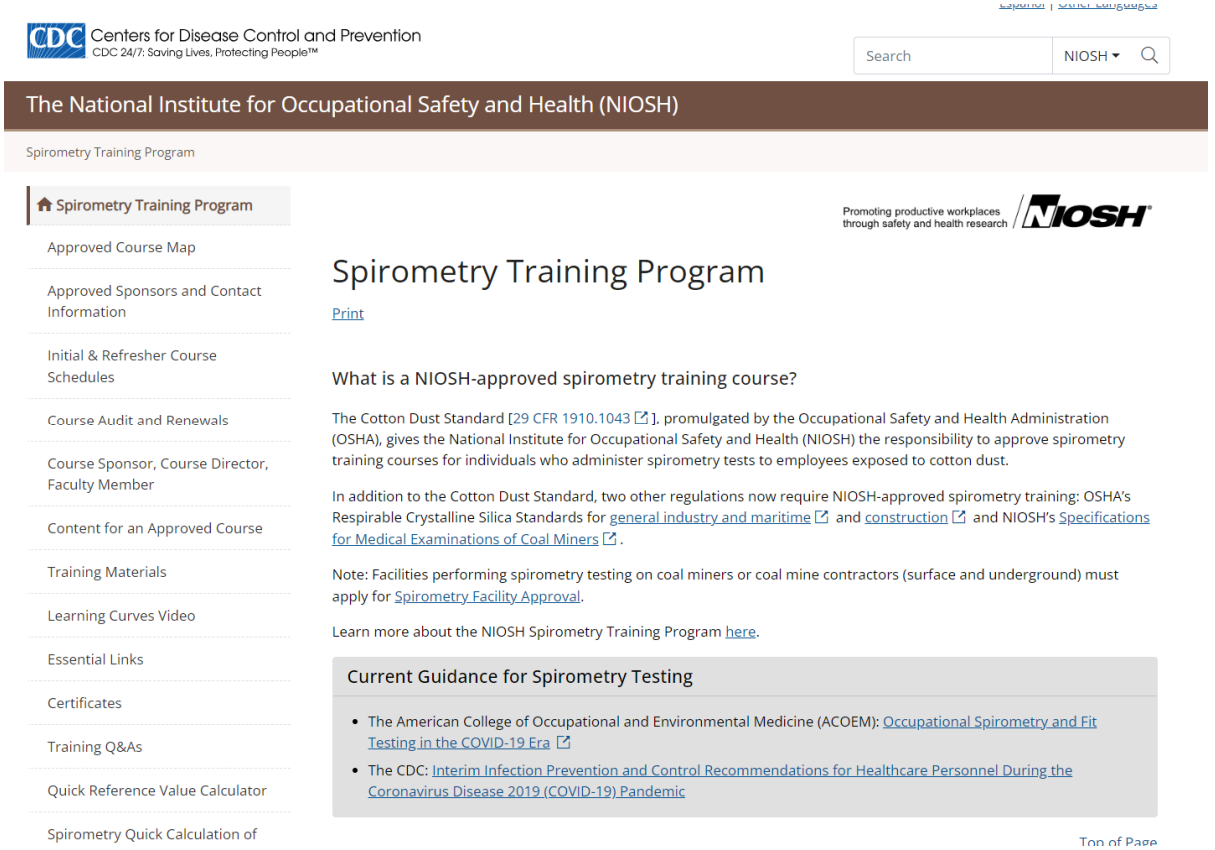
- spirXpert - ERS

American Lung Association Spirometry



A Little Deeper: AARC Spirometry Course

CDC NIOSH Spirometry Training Program



Centers for Disease Control and Prevention
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The National Institute for Occupational Safety and Health (NIOSH)

Spirometry Training Program

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Spirometry Training Program

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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?

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