

# Pulmonary Function Symposium - 2023

## Spirometry Workshop

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# Overall Objective

To be better adept in obtaining useful and accurate information while performing Spirometry. This will provide the medical team meaningful information to diagnosis and treat patients with lung disease. This objective will be met through demonstration, practice and sharing information by participants in this workshop

# Objectives

- Review of information obtained from Spirometry
- Review acceptability and repeatability Criteria for Spirometry
- Demonstrate and practice performing Spirometry tests.
- Discuss coaching tips as result of demonstration.
- Review of common problems when performing PFTs

# Indications for Testing

- Diagnosis – i.e. For detecting the presence or absence of lung dysfunction suggested by history or physical indicators.
- Monitoring – i.e. To assess changes in lung function over time or following administration of, or change of, therapy.
- Disability/impairment evaluations - To assess patients as part of a rehabilitation program.
- Other – i.e. Research and clinical trials.

# Indications for Testing

**Table 1.** Indications for Spirometry

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## 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
-

# Contraindications to Testing

- Contraindications to testing are relative, the decision to perform spirometry is determined by the ordering provider
- Hemoptysis of unknown origin
- Untreated pneumothorax
- Recent myocardial infarction
- Recent or untreated pulmonary embolism
- Thoracic, abdominal, or cerebral aneurysms
- Recent abdominal, thoracic, eye or brain surgery
- Presence of an acute disease process that might interfere with test performance

# Contraindications to Testing

**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.]

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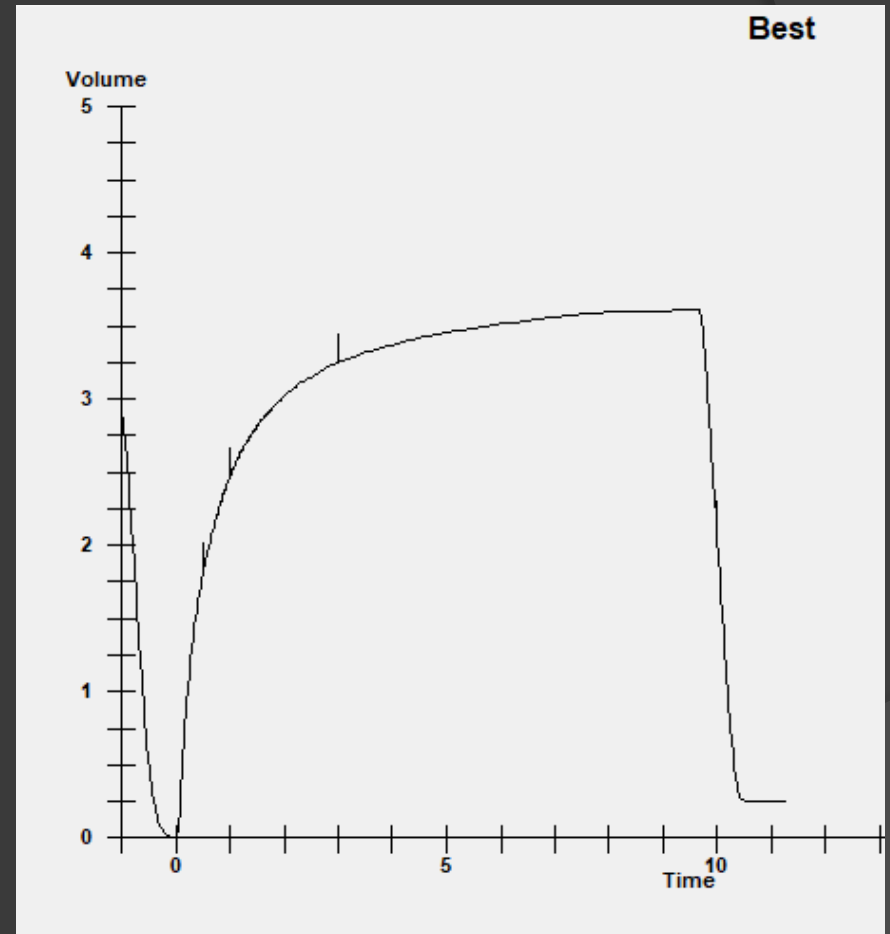
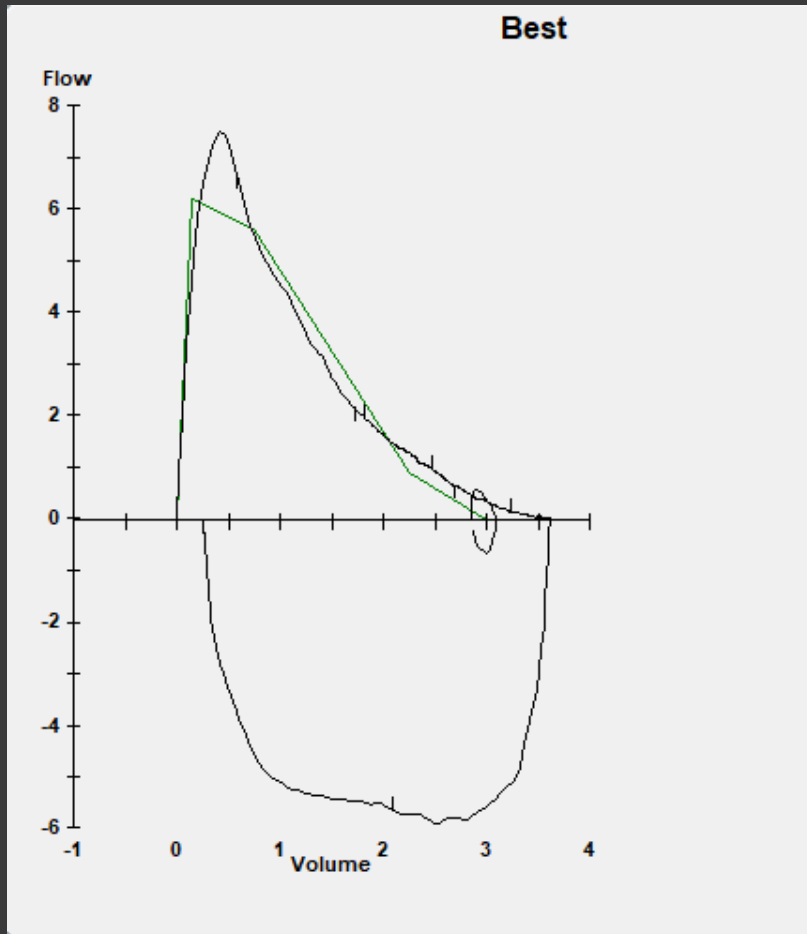
# Complications to Testing

- ⦿ Pneumothorax
- ⦿ Increased intra-cranial pressure, increasing the risk of intra-cranial bleeding
- ⦿ Syncope, dizziness, light-headedness
- ⦿ Chest pain
- ⦿ Coughing
- ⦿ Contraction of infections
- ⦿ Oxygen desaturation due to interruption of oxygen therapy
- ⦿ Bronchospasm



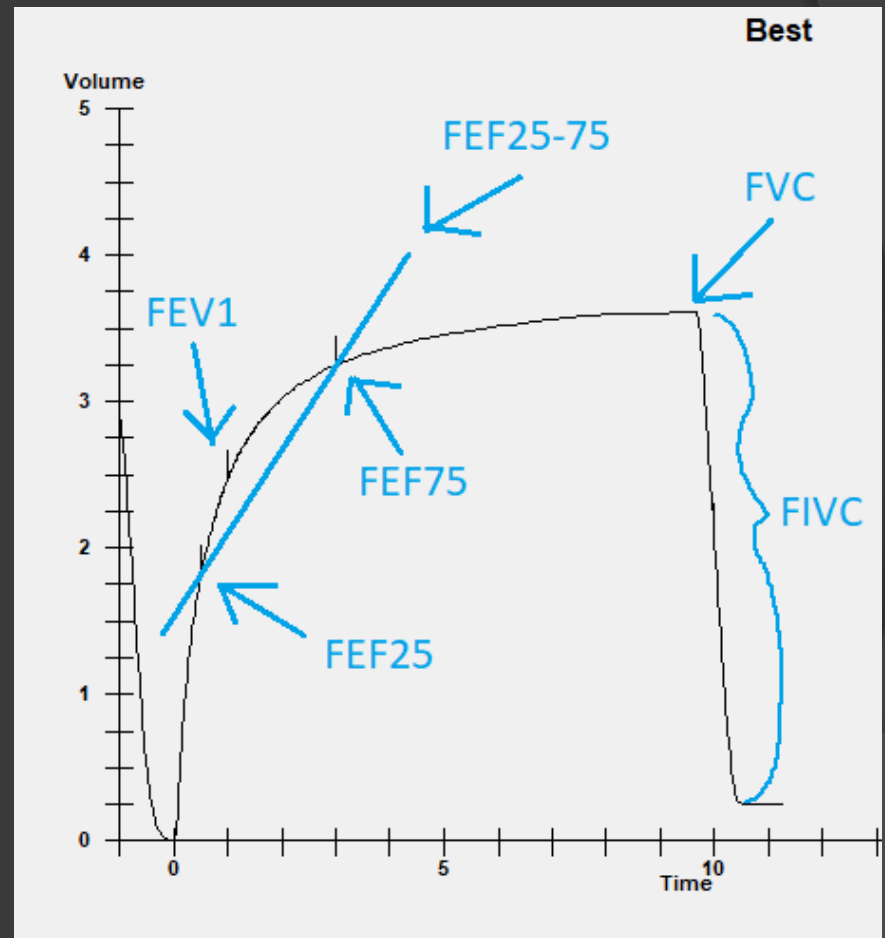
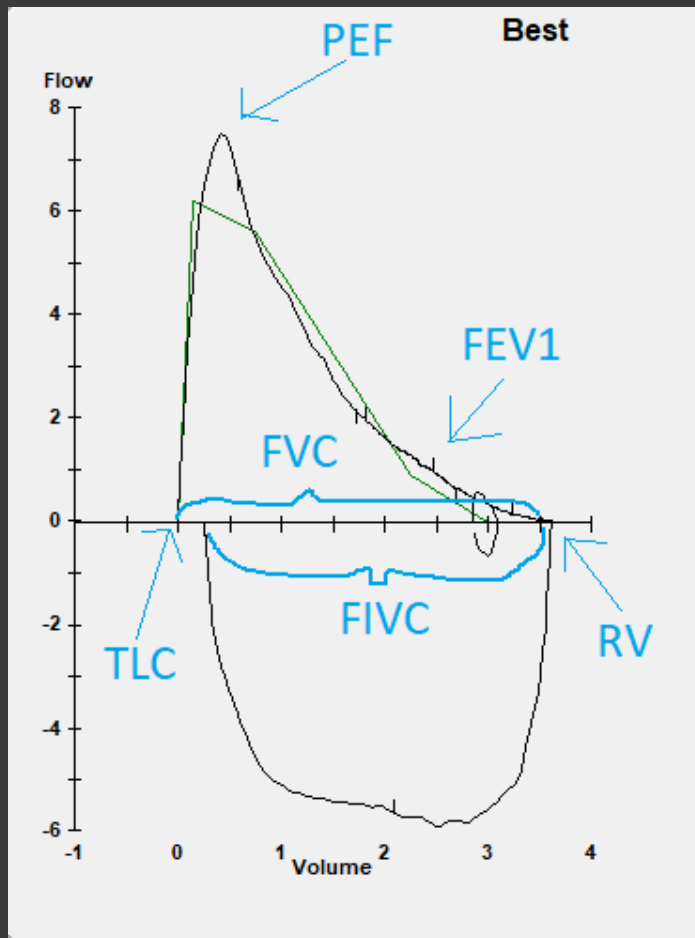
# Label Flow Volume Loop and Spirogram

FVC, FEV1, PEF, FEF25-75%, FEF25%, FEF75%, FIVC



# Label Flow Volume Loop and Spirogram

FVC, FEV1, PEF, FEF25-75%, FEF25%, FEF75%, FIVC



# Spirometry

- Pt. is asked to breathe normally for a few breathes, then inhale rapidly to TLC, then exhale with maximal effort until they are completely empty, and finally inhale with maximal effort until they are completely full.
- Measures: FVC, FEV1, FEF25, FEF75, PEF, FIVC, and PIF.
- FEV1/FVC, FEF25-75 are calculated.

# What is Acceptability Criteria?

- ⦿ Take a moment now to write down what the acceptability criteria are?

# Criteria for Acceptability

- Start of Test Criteria – No hesitation (Back extrapolated volume within 5% or 100 ml of FVC, whichever is greater.)
- Achieve on of the three End of Forced Expiration (EOFE) indicators –
  - 1. Expiratory plateau ( $\leq 0.025$  L in the last 1 s of expiration)
  - 2. Expiratory time  $\geq 15$  s
  - 3. FVC is within the repeatability tolerance of or is greater than the largest prior observed FVC
- No cough during first second
- No glottic closure, or early termination that influences the measurement
- No obstructed mouthpiece or spirometer
- No evidence of a faulty zero-flow setting
- No evidence of leak
- 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

# Criteria for Acceptability

**Table 7.** Summary of Acceptability, Usability, and Repeatability Criteria for FEV<sub>1</sub> and FVC

Acceptability and Usability Criterion	Required for Acceptability		Required for Usability	
	FEV <sub>1</sub>	FVC	FEV <sub>1</sub>	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 <sup>†</sup>				
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 <sup>‡</sup>	Yes	Yes	No	No

**Repeatability criteria** (applied to acceptable FVC and FEV<sub>1</sub> 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<sub>1</sub> 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<sub>1</sub> values must be ≤0.100 L or 10% of the highest value, whichever is greater

*Definition of abbreviations:* BEV = back-extrapolated volume; EOFE = end of forced expiration; FEV<sub>0.75</sub> = forced expiratory volume in the first 0.75 seconds; FIVC = forced inspiratory VC.

The grading system (Table 10) will inform the interpreter if values are reported from usable maneuvers not meeting all acceptability criteria.

\*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 FEV<sub>0.75</sub>.

<sup>†</sup>Occurs when the patient cannot expire long enough to achieve a plateau (e.g., children with high elastic recoil or patients with restrictive lung disease) or when the patient inspires or comes off the mouthpiece before a plateau. For within-maneuver acceptability, the FVC must be greater than or within the repeatability tolerance of the largest FVC observed before this maneuver within the current prebronchodilator or the current post-bronchodilator testing set.

<sup>‡</sup>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.

# Exceptions to Criteria for Acceptability

- BEV - Patients with upper airway obstruction or neuromuscular disease are often unable to initiate a rapid increase in flow, and the BEV limit may be exceeded.

# Repeatability Criteria

Repeatability (applied to acceptable FVC and FEV1 values)

- Age > 6 yr: 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.
- 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 FEV1 values must be <0.100 L or 10% of the highest value, whichever is greater

**Test can be acceptable but not repeatable. When acceptable maneuvers are achieved with good coaching it is not difficult to get repeatability**



# Grading FVC and FEV1

- FVC and FEV1 are graded separately
- Grade both Pre and Post maneuvers separately

**Table 10.** Grading System for FEV<sub>1</sub> 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 OR 1 acceptable	>0.250 L N/A	>0.200 L* N/A
U	0 acceptable AND ≥1 usable	N/A	N/A
F	0 acceptable and 0 usable	N/A	N/A

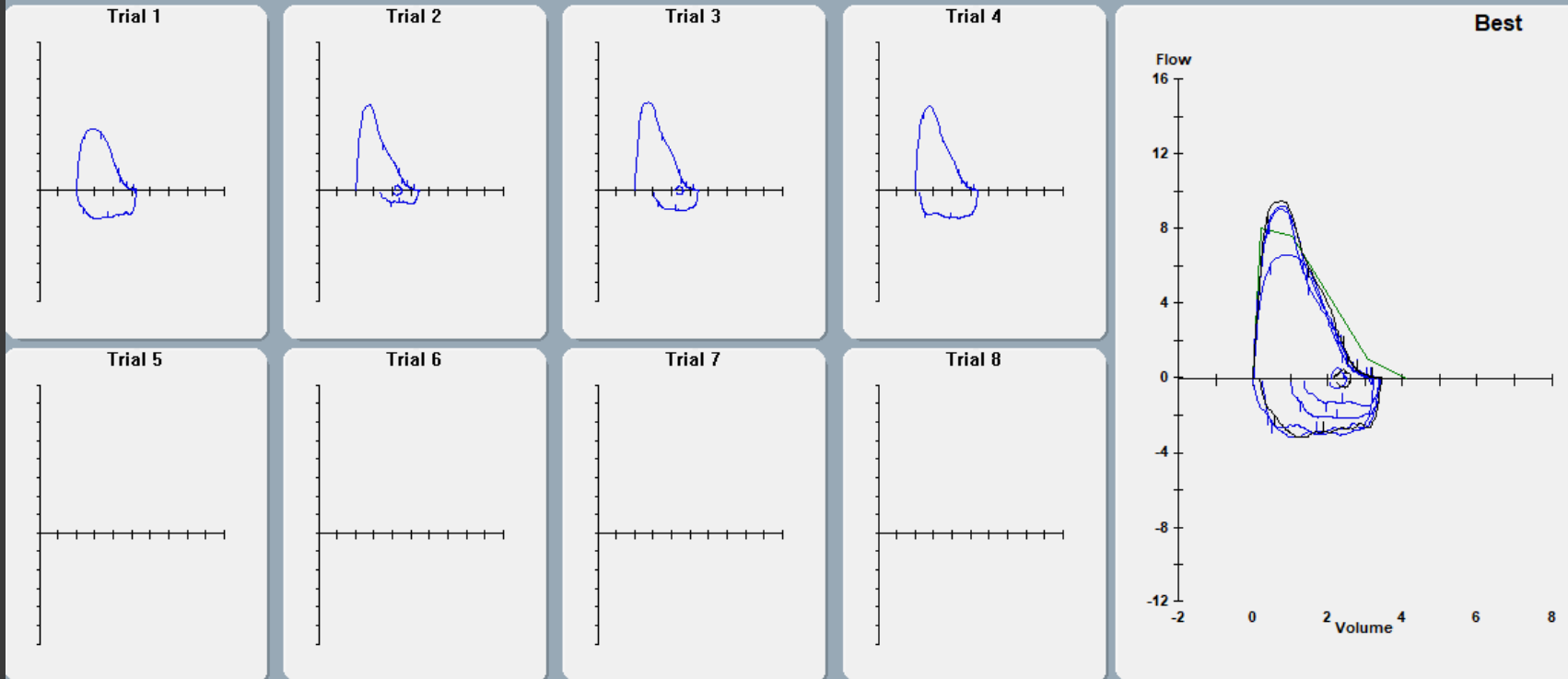
*Definition of abbreviation:* N/A = not applicable.

The repeatability grade is determined for the set of prebronchodilator maneuvers and the set of post-bronchodilator maneuvers separately. The repeatability criteria are applied to the differences between the two largest FVC values and the two largest FEV<sub>1</sub> 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.

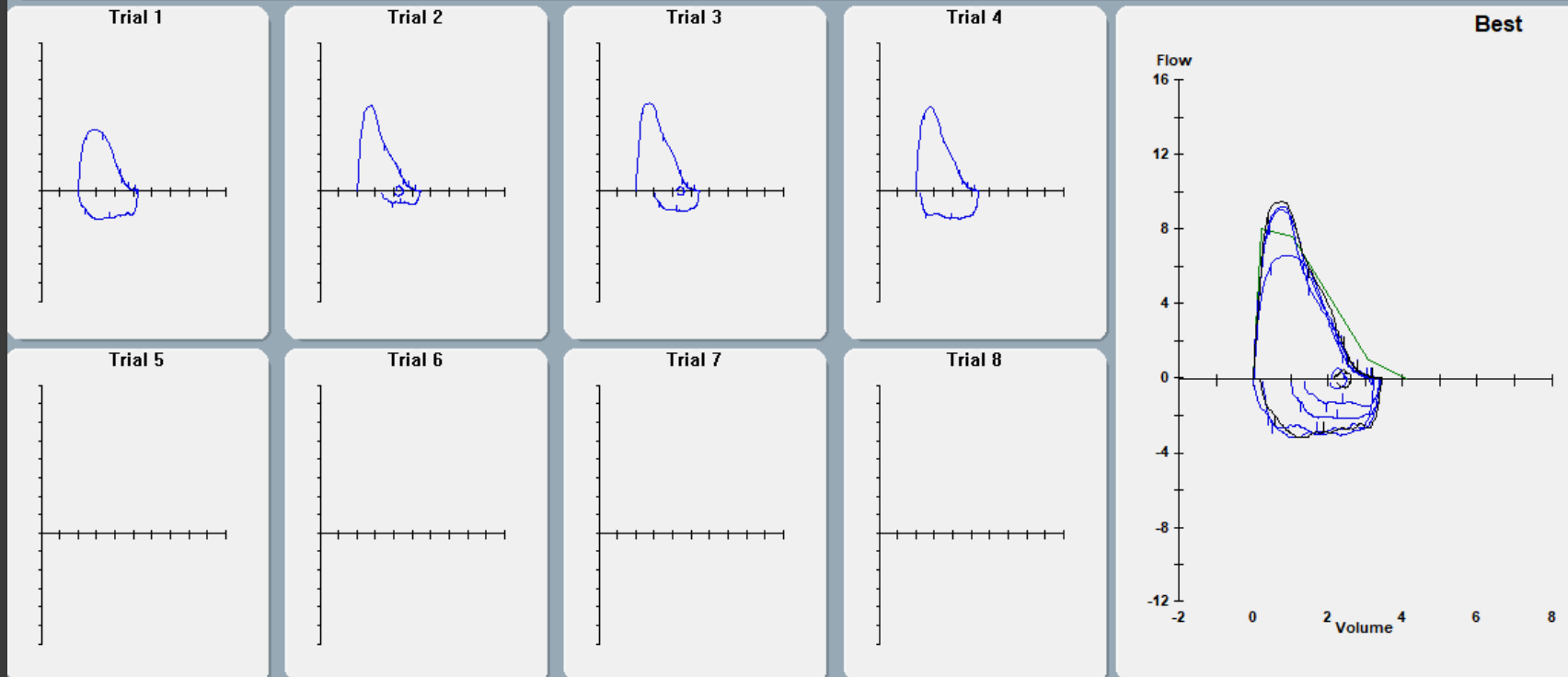
# Grade the Test

	Ref	Best	% Ref	1	2	3	4
FVC	4.13	3.44	83	3.25	3.43	3.44	3.39
FEV1	3.31	2.82	85	2.71	2.82	2.82	2.81
FEV1/FVC	80	82	103	83	82	82	83
FEF75%	1.06	1.17	110	1.32	1.14	1.17	1.21
PEF	8.14	9.58	118	6.67	9.28	9.58	9.11



# FVC Grade A, FEV1 Grade A

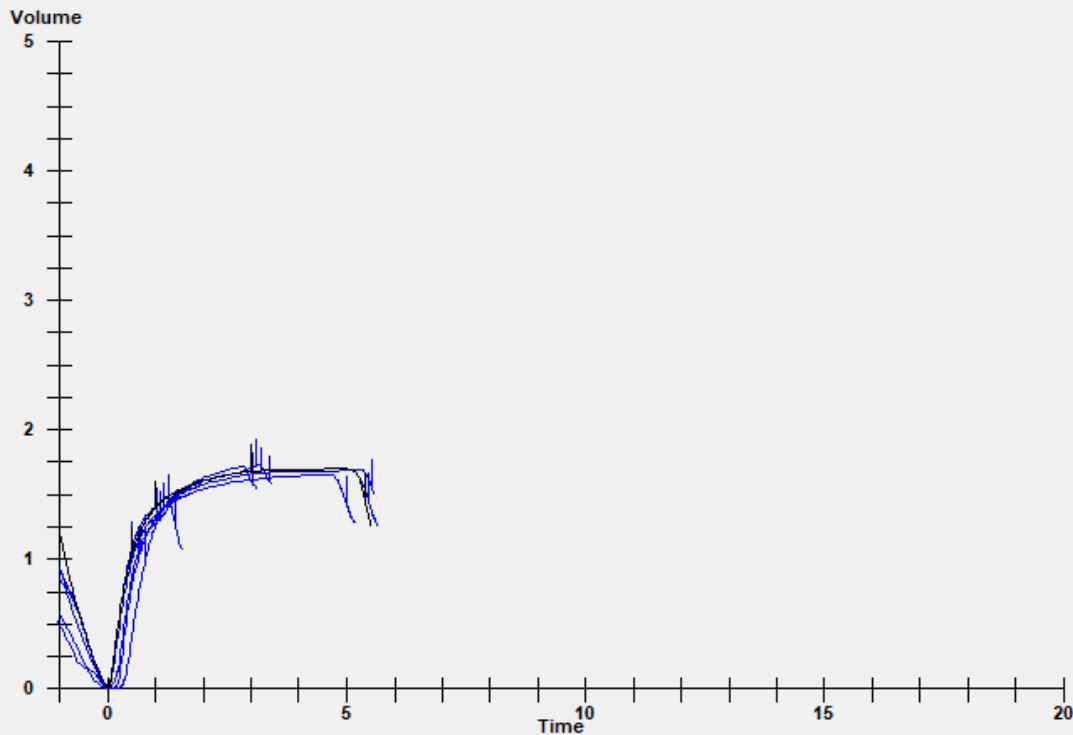
	Ref	Best	% Ref	1	2	3	4
FVC	4.13	3.44	83	3.25	3.43	3.44	3.39
FEV1	3.31	2.82	85	2.71	2.82	2.82	2.81
FEV1/FVC	80	82	103	83	82	82	83
FEF75%	1.06	1.17	110	1.32	1.14	1.17	1.21
PEF	8.14	9.58	118	6.67	9.28	9.58	9.11



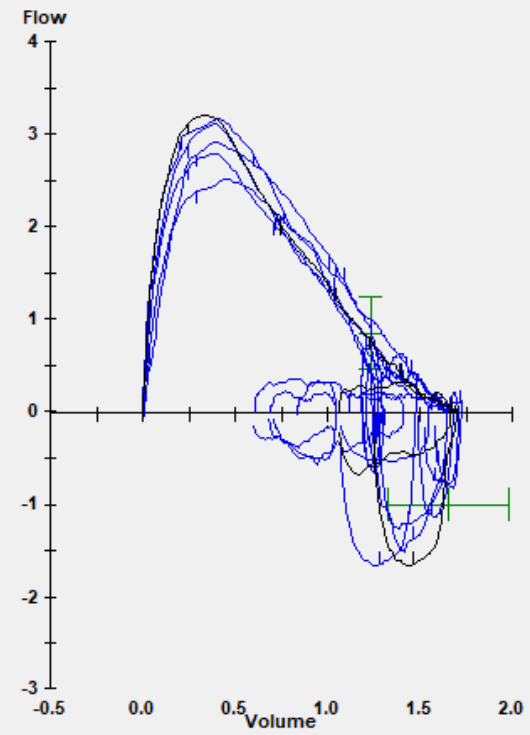
# Grade the Test

	Ref	Best	% Ref	1	2	3	4	5	6
FVC	1.65	1.70	103	1.49	1.72	1.73	1.65	1.70	1.68
FEV1	1.46	1.42	97	1.42	1.47	1.34	1.36	1.42	1.41
FEV1/FVC	89	83	94	95	86	77	82	83	83
FEF75%	0.86	0.77	90	1.41	0.99	0.34	0.70	0.77	0.80
PEF		3.24		3.20	2.56	2.96	2.82	3.24	3.14

Best



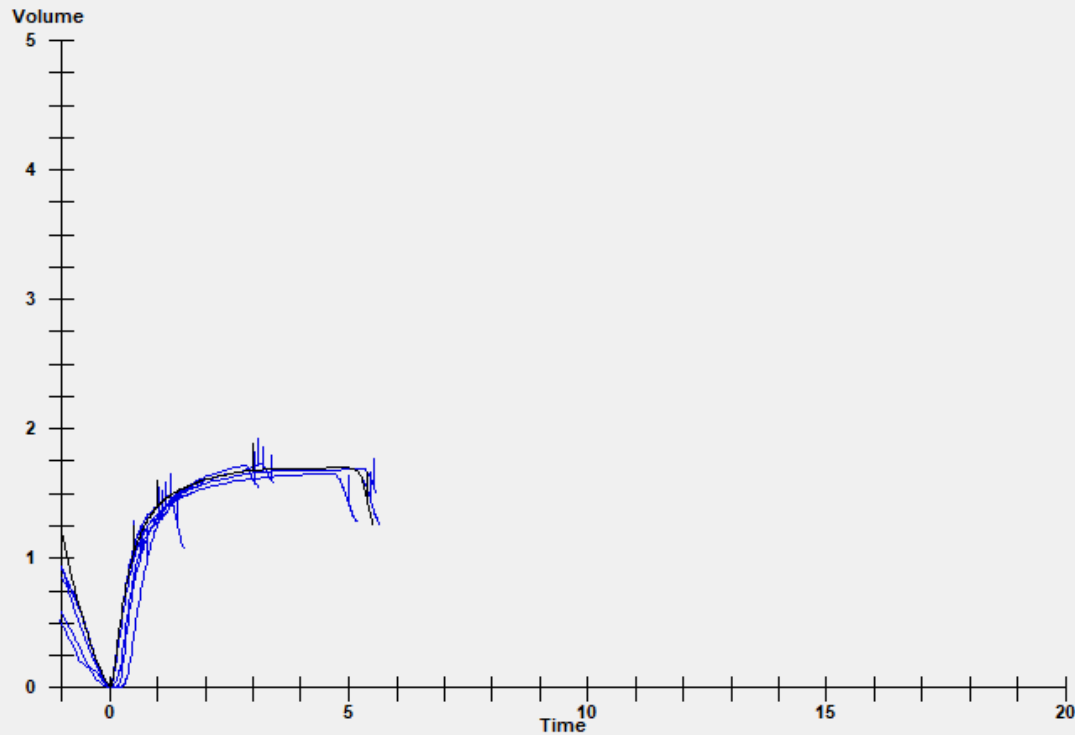
Best



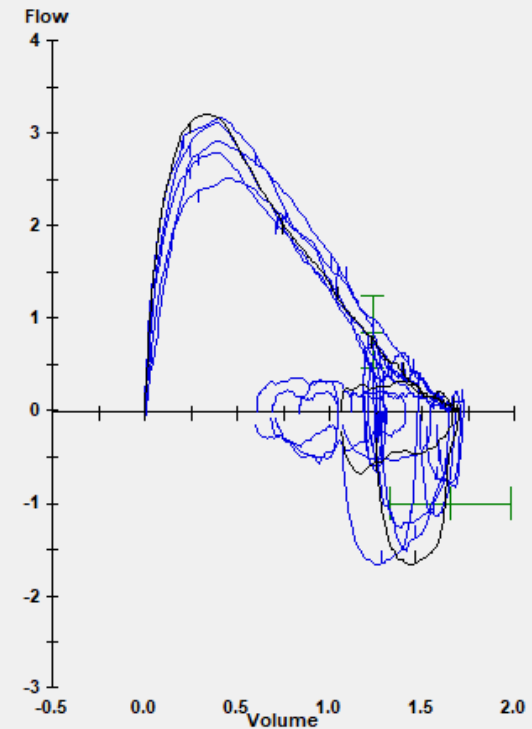
# FVC Grade A, FEV1 Grade A

	Ref	Best	% Ref	1	2	3	4	5	6
FVC	1.65	1.70	103	1.49	1.72	1.73	1.65	1.70	1.68
FEV1	1.46	1.42	97	1.42	1.47	1.34	1.36	1.42	1.41
FEV1/FVC	89	83	94	95	86	77	82	83	83
FEF75%	0.86	0.77	90	1.41	0.99	0.34	0.70	0.77	0.80
PEF		3.24		3.20	2.56	2.96	2.82	3.24	3.14

Best



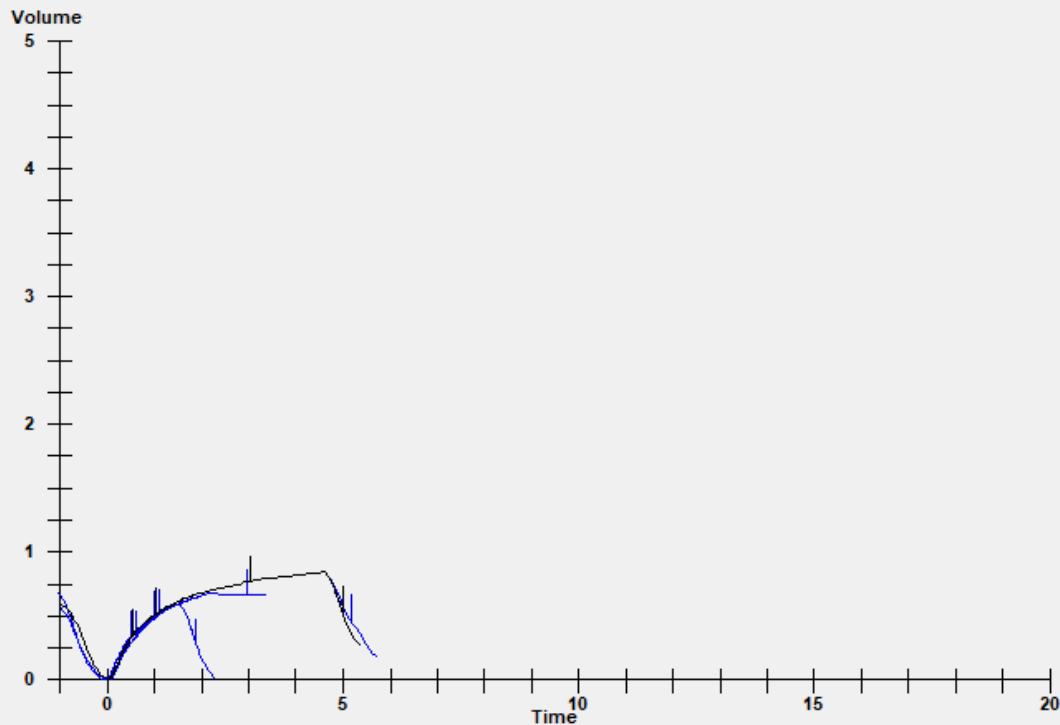
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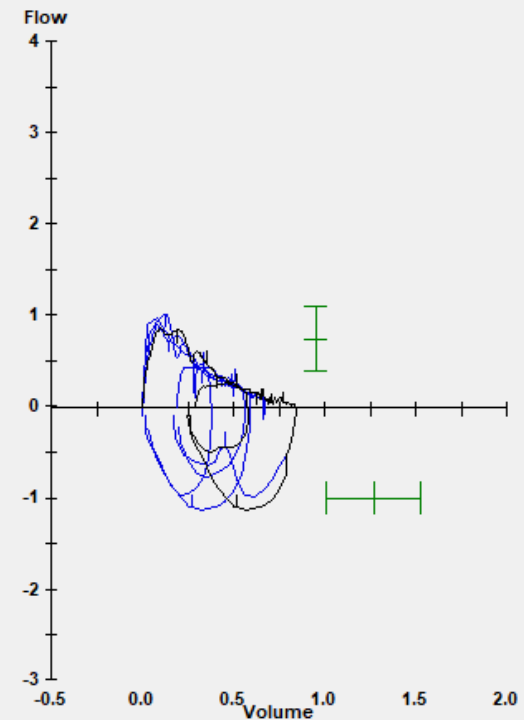
# Grade the Test (6-Year-old patient)

	Ref	Best	% Ref	1	2	3
FVC	1.27	0.84	66	0.59	0.84	0.68
FEV1	1.15	0.53	46	0.51	0.53	0.50
FEV1/FVC	91	62	69	87	62	73
FEF75%	0.76	0.17	23	0.36	0.17	0.27
PEF		1.04		1.04	0.88	0.92

Best



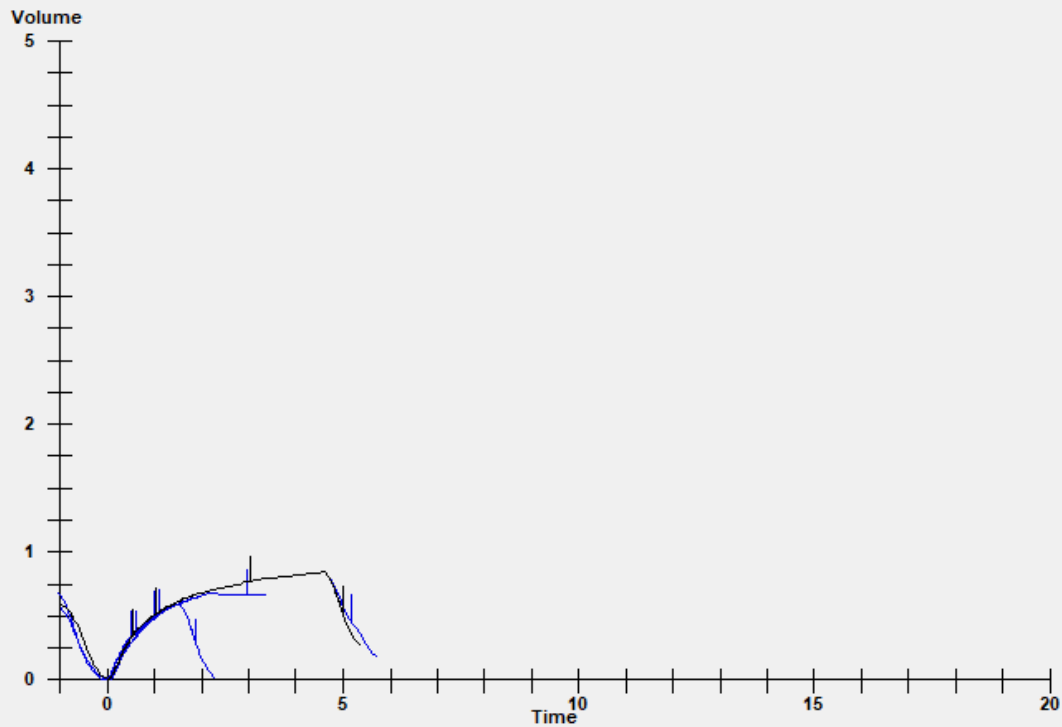
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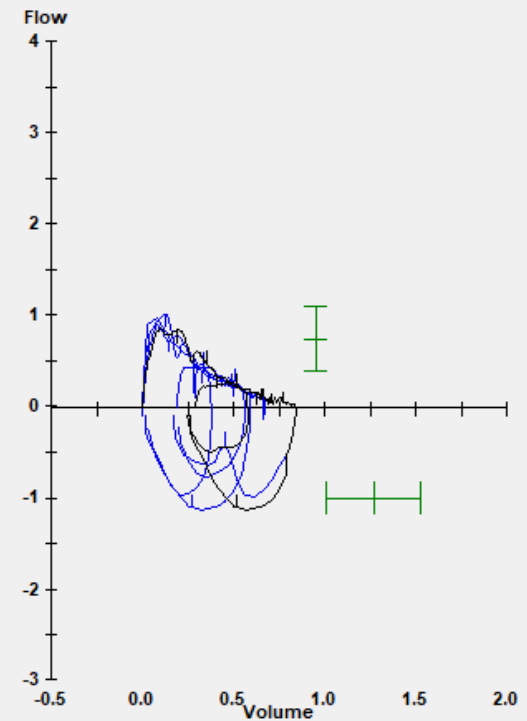
# FVC Grade U, FEV1 Grade A

	Ref	Best	% Ref	1	2	3
FVC	1.27	0.84	66	0.59	0.84	0.68
FEV1	1.15	0.53	46	0.51	0.53	0.50
FEV1/FVC	91	62	69	87	62	73
FEF75%	0.76	0.17	23	0.36	0.17	0.27
PEF		1.04		1.04	0.88	0.92

Best



Best



# Demonstration

Use the worksheet provided to make comments during the demonstration

- Test Preparation
- Test instructions
- Test Performance
- Corrective Feedback
- Have acceptability and reproducibility criteria been met?



# Test Preparation

- Hand hygiene for both you and the patient
- Confirm patient identification, age, birth sex, ethnicity, etc.
- Measure weight and height without shoes
- Note respiratory symptoms (SpO<sub>2</sub>, HR)
- Ask about activities:
  - Smoking, Vaping, Cannabis use history (should withhold for 1 hr)
  - Medication use (withhold BDs?, include time last taken)
  - Any relative contraindications flagged on the requisition/interview
  - Consuming intoxicants within 8 h before testing
  - Performing vigorous exercise within 1 h before testing
  - Wearing clothing that substantially restricts full chest and abdominal expansion
  - Acute Influenza like illness/COVID symptoms

# Test Instruction

- ⦿ Simplify the instructions
- ⦿ Demonstrate test - can't be emphasized enough
- ⦿ Evaluate each patient individually
- ⦿ Decide on an appropriate teaching method

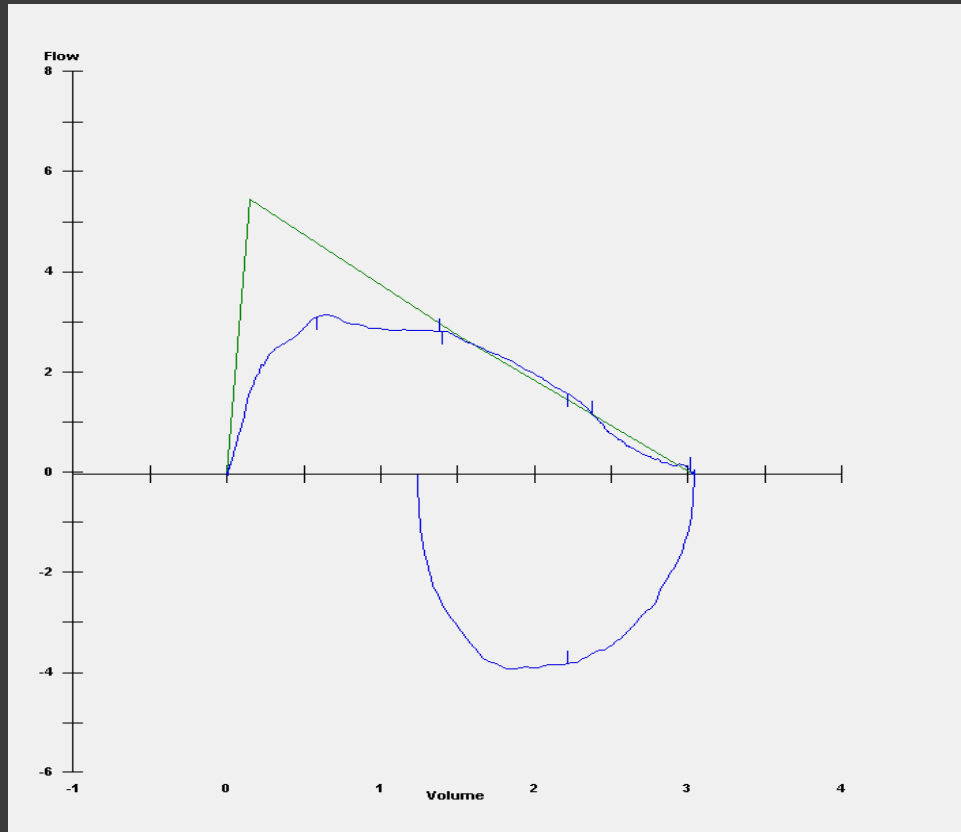
# Test Performance and Feedback

- Evaluate each attempt during and after – Focus first on areas not done properly. Corrective feedback
- Positive reinforcement, i.e. let them know what they have done correctly.
- If necessary, stop the test and start again.
- Generally if not able to get good results in 8 attempts it may be time to give up.

# Acceptable and Repeatable

- ⦿ Was this achieved?
- ⦿ 3 acceptable efforts
- ⦿ 2 within 150ml

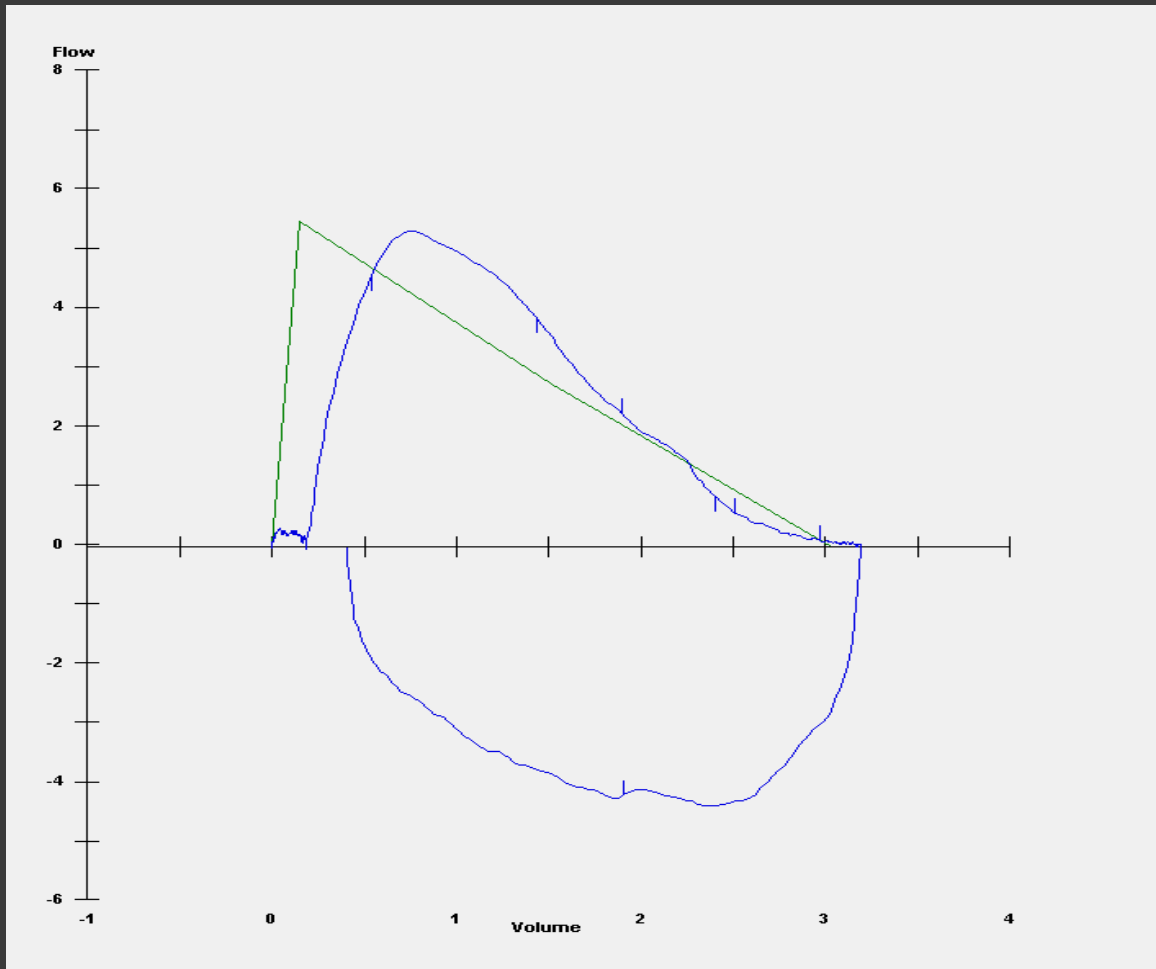
# Problem 1



# Submaximal Effort

- With adults you can explain that they need to blow out hard, i.e. use chest muscles rather than throat as soon as they are “full”.
- It is imperative that you demonstrate before the test
- Doing the test with them, ie. “yell” blow or even stomp your foot. You can not sit “passively” while they blow out. Sometimes scaring them works.
- Often they still use their throats to try to get maximal effort. You can say it is “like a punch in the stomach”. This works well with kids.
- Candle animation works well if all else fails.
- Watch patient - Do they look like they are blowing out hard?
- Submaximal efforts are acceptable for the computer.

# Problem 2

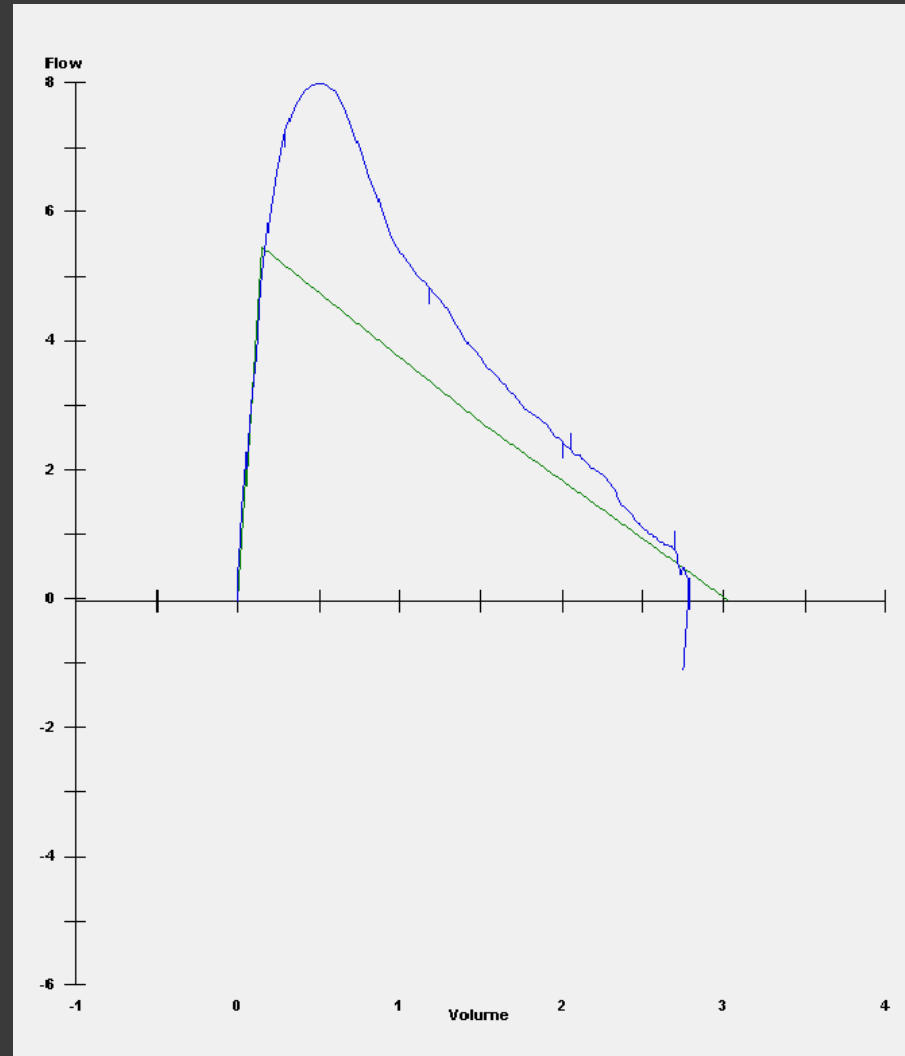


# Hesitation

- ⦿ This is the start of test criteria where extrapolated volume is less than 100ml of the FVC (or 5% whichever is greater)
- ⦿ Don't hold breath when full, must blow out as soon as instructed.
- ⦿ This is often corrected with submaximal blows.
- ⦿ Must be careful not to ask patient to blow out before they are full. Need to look at screen and patient almost at the same time.
- ⦿ Remember if there is a little hesitation it still may be acceptable



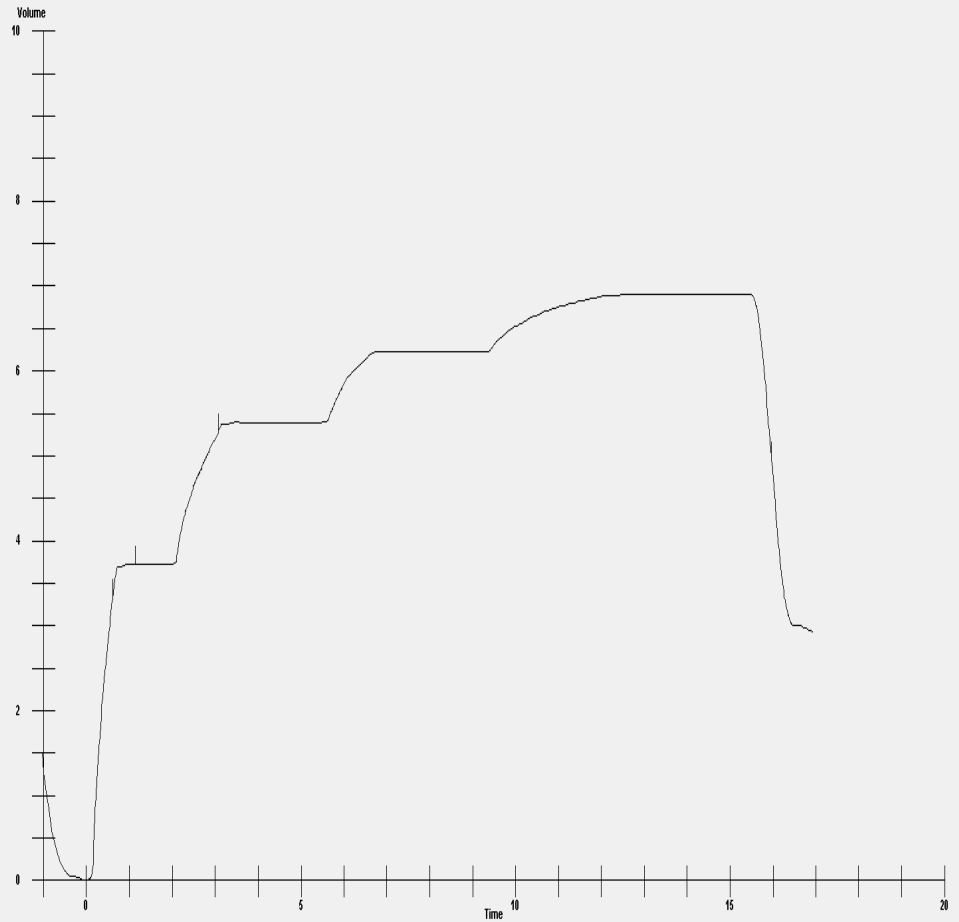
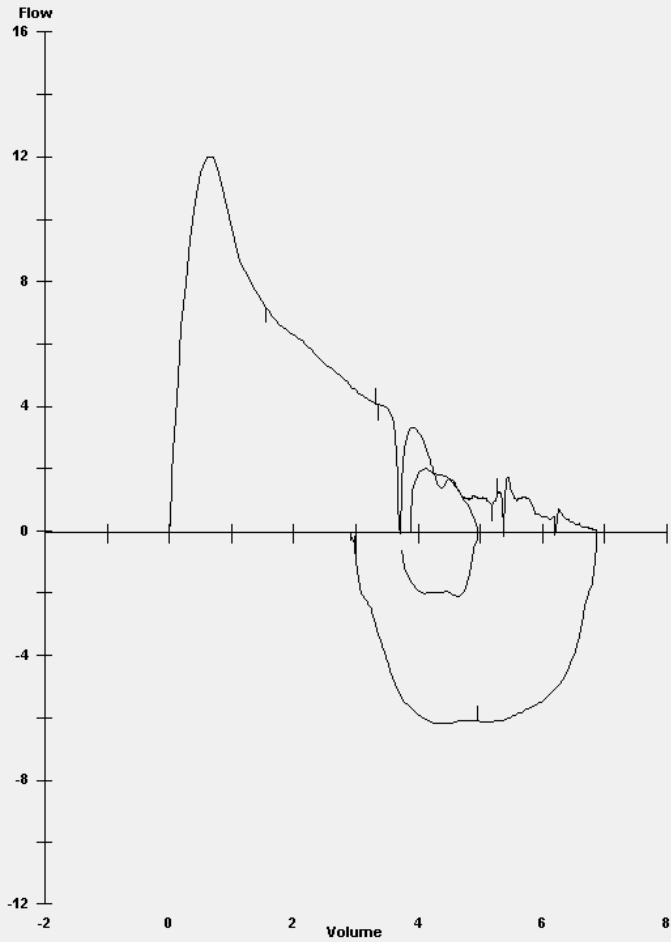
# Problem 3



# Premature Closure/No Plateau

- ⦿ Blowing out to RV is the most difficult concept for children and some adults.
- ⦿ It is instinct to breathe in at the end of a normal breath out. Patient must be reminded that there is still more air left in the lungs.
- ⦿ Do a slow maneuver
- ⦿ Practice off of the mouthpiece
- ⦿ Verbal cues
  - Blow out all of mommy's candles on her birthday cake
  - Blow up a balloon

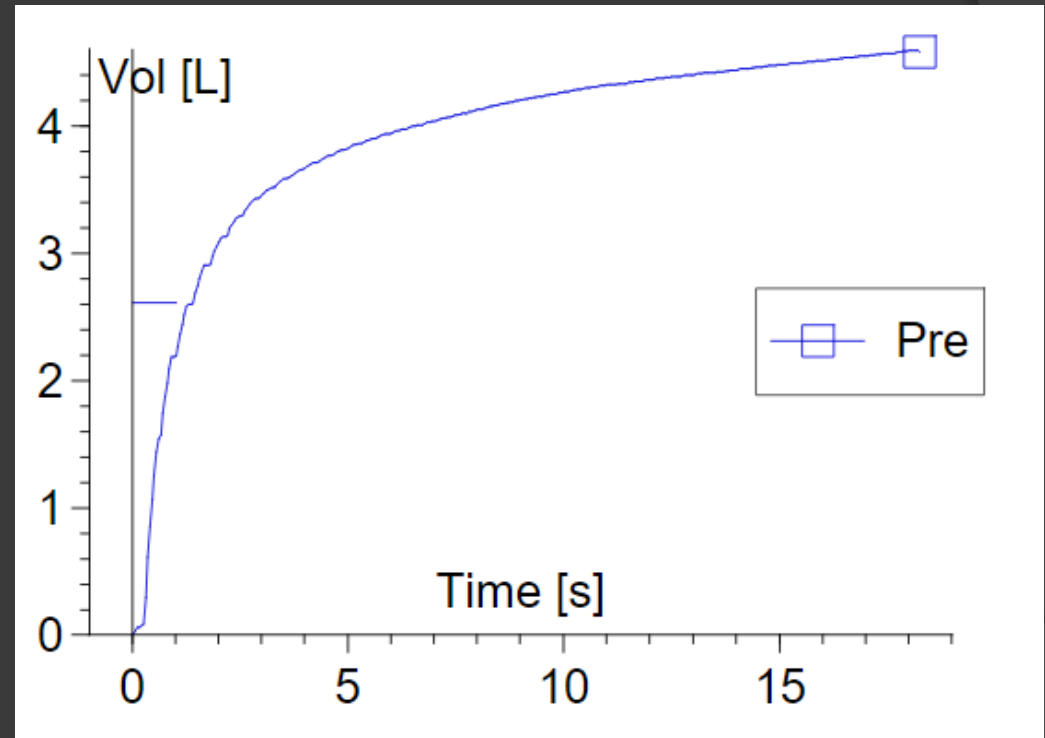
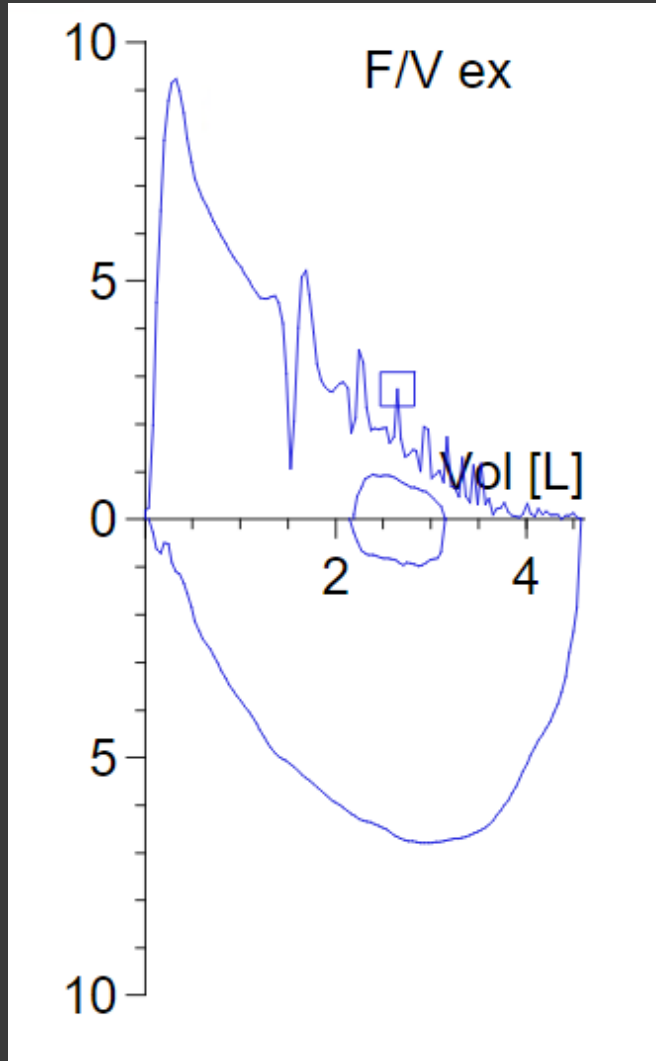
# Problem 4



# Glottic Closure

- ⦿ They must be encouraged to relax at the end of the blow and continue. “Bearing down” does contribute to closing of the glottis
- ⦿ Relax the throat, use the stomach or core
- ⦿ Visualize candles to continue to blow out

# Problem 5

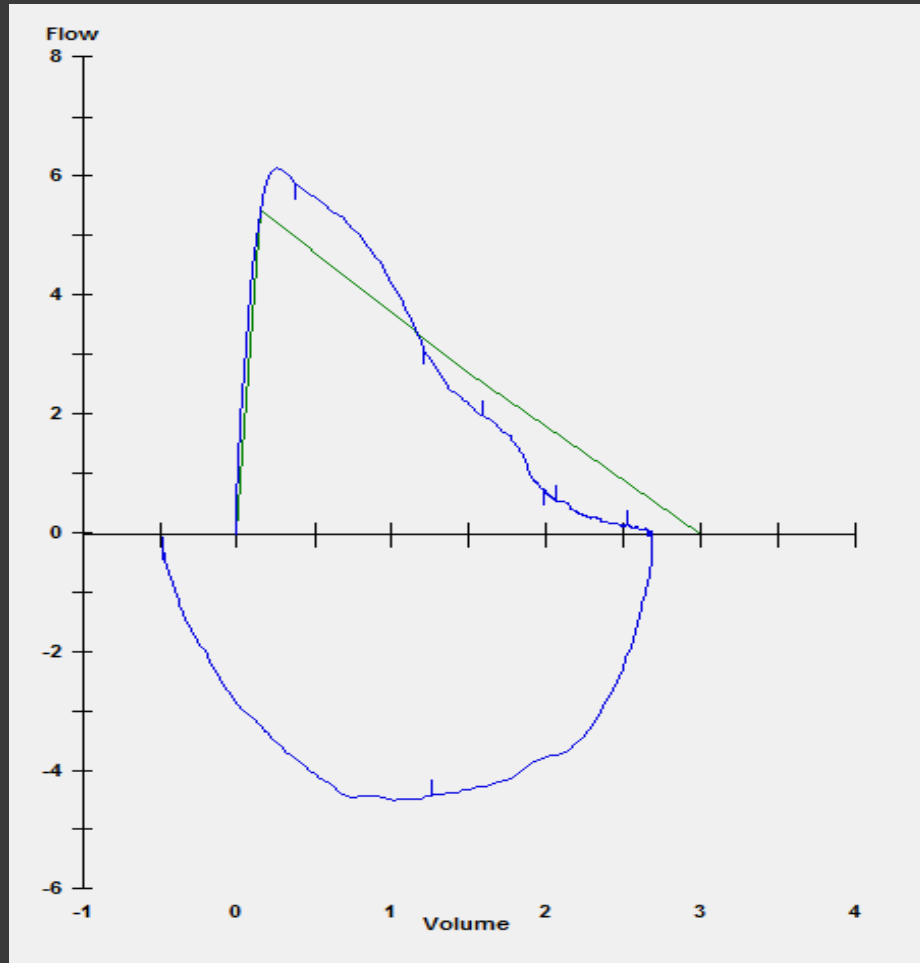


# Coughing

- ⦿ When blow with “throat” rather than “chest muscles” coughing can occur. If cough too early in the maneuver the FEV<sub>1</sub> may be affected. Usually if it is only one cough, the patient can be encouraged to “hold” off on the cough until finished.
- ⦿ If the coughing “fit” occurs towards the very end, this may not be so bad, i.e FEV<sub>1</sub> will still be good. Some patients can continue to blow out as they cough and need to be coached to do so. Can also demonstrate.
- ⦿ The problem is with those who cough throughout the test. Maybe a drink helps??

- If patient has a Restrictive pattern they will tend to cough at the very beginning of the maneuver to the point that they will not be able to do test. Can try coaching to withhold cough until after the first second.
- If patient has an obstructive pattern they will tend to cough at the end of the maneuver. May not fully breath out to RV.

# Problem 6

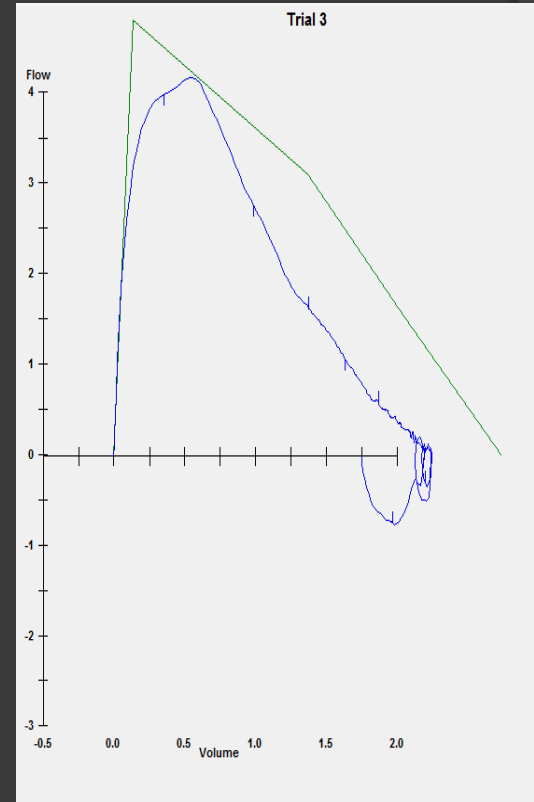
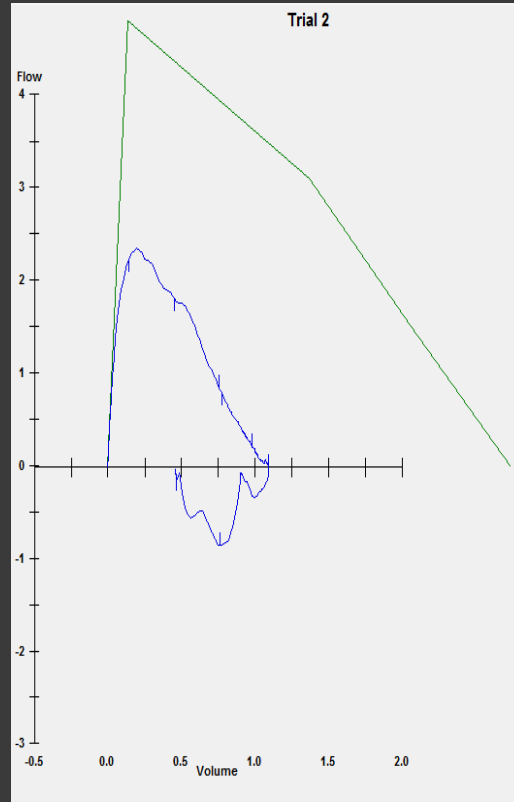
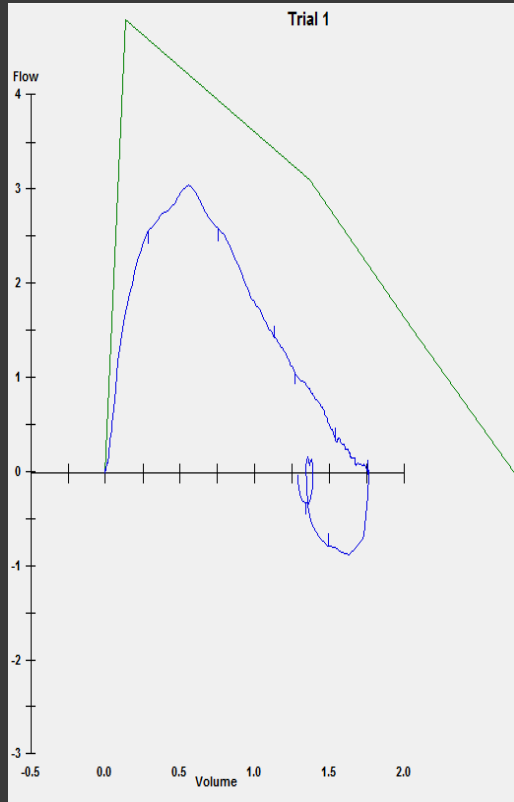




# Sub Maximal Inspiration

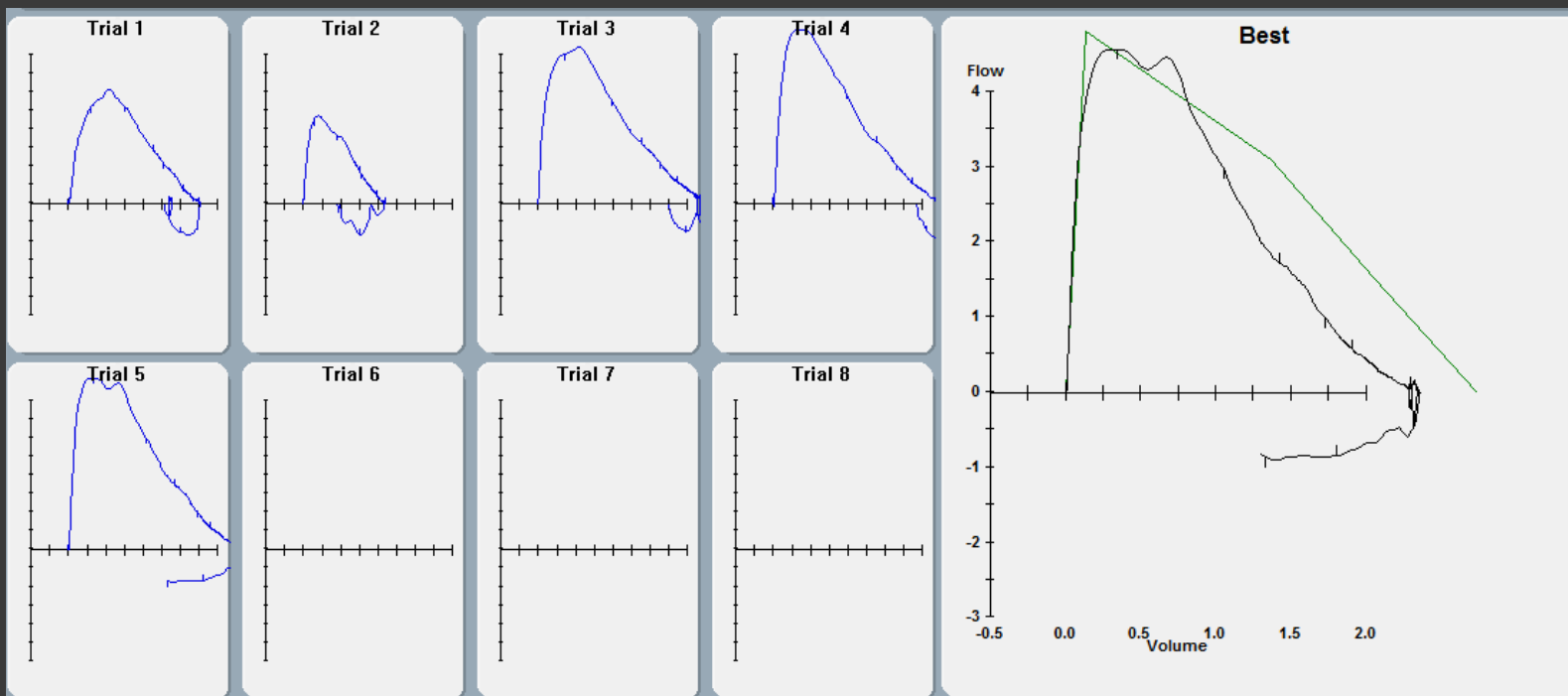
- ⦿ In our attempt to be sure that there is no hesitation at the beginning of the effort we may inadvertently cause patient not to breathe in fully.
- ⦿ Having the patient repeat the maneuver after the first forced expiration can sometimes correct for this if the patient is able.
- ⦿ Have the patient exhale first, then inhale to TLC.
- ⦿ Watch the patient, check for complete chest rise before yelling “blow”

# Problem 7



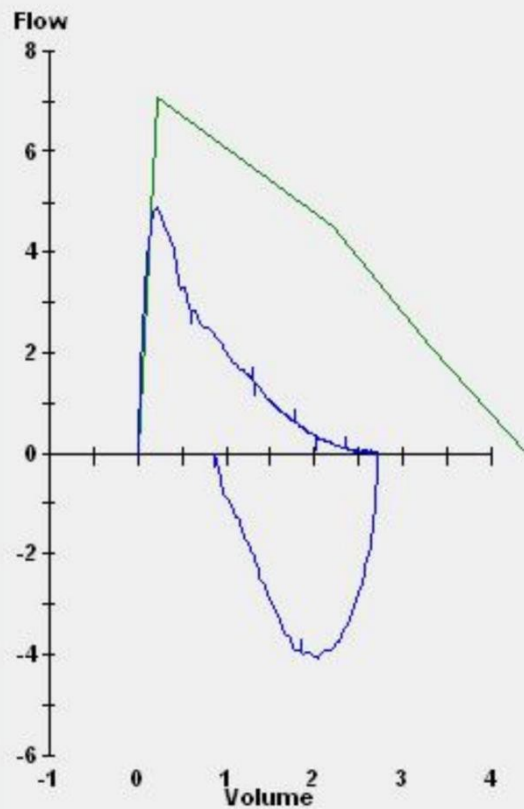
# Submax inspiration - Summary

	Ref	Best	% Ref	1	2	3	4	5
FVC	2.75	2.37	86	1.77	1.10	2.26	2.27	2.37
FEV1	2.43	1.94	80	1.56	1.00	1.90	1.89	1.94
FEV1/FVC	89	82		88	91	84	83	82
PEF	4.84	4.60	95	3.08	2.37	4.21	4.69	4.60

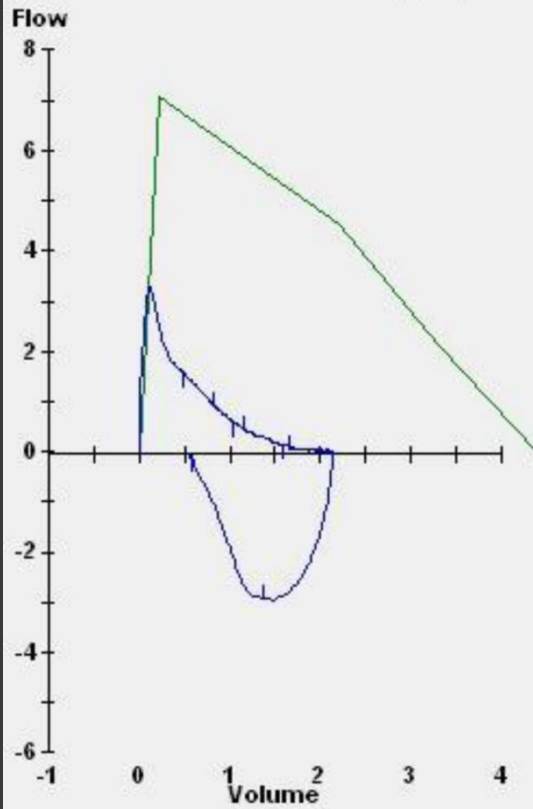


# Problem 8

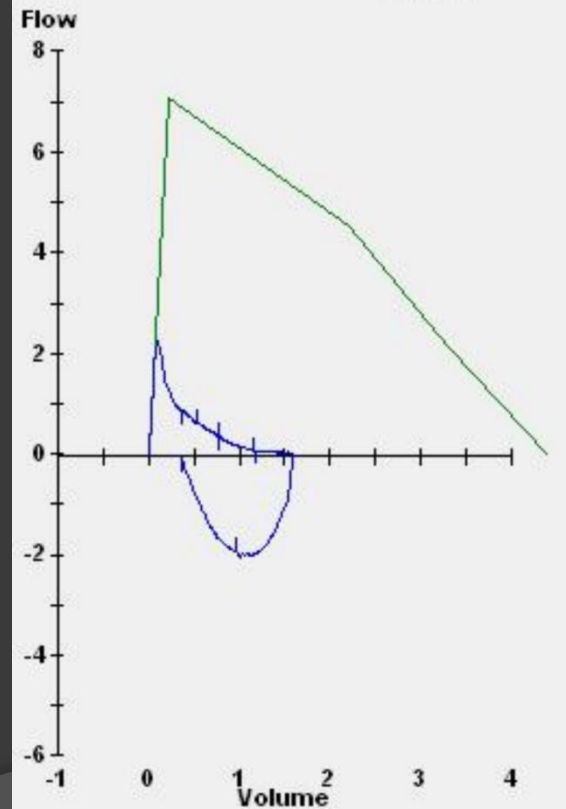
Trial 1

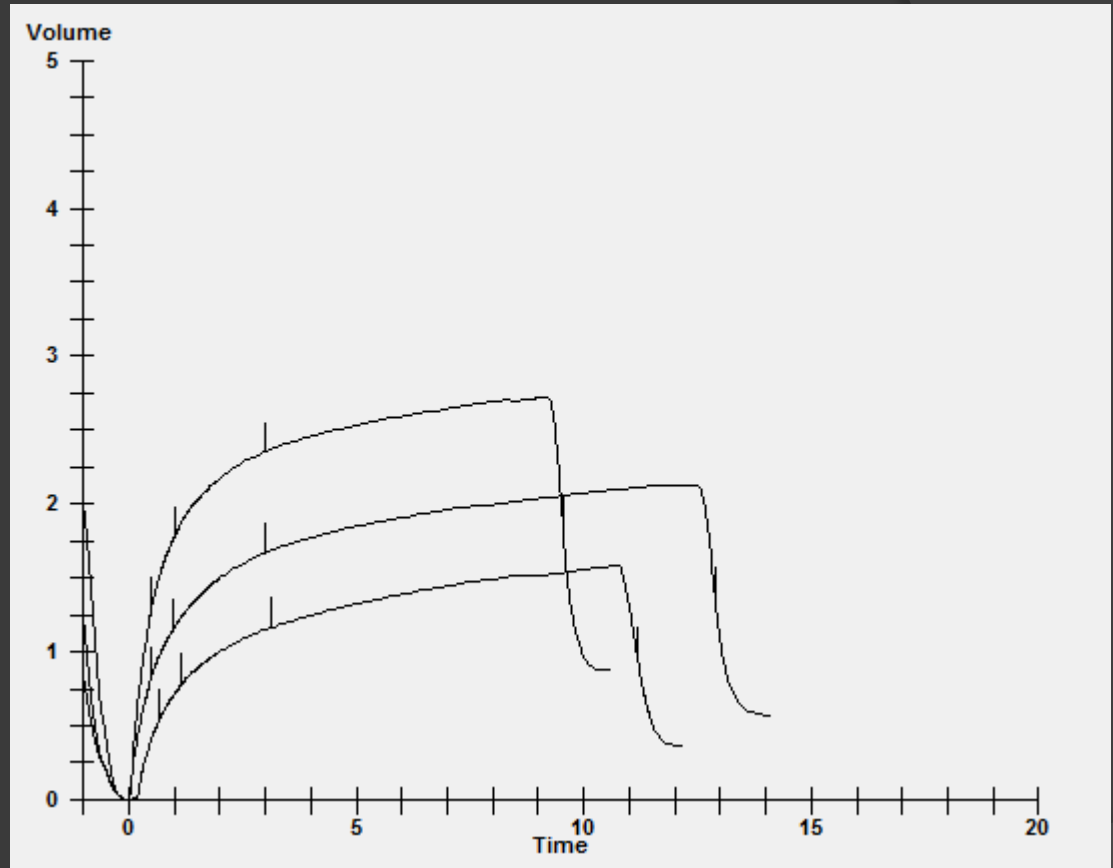
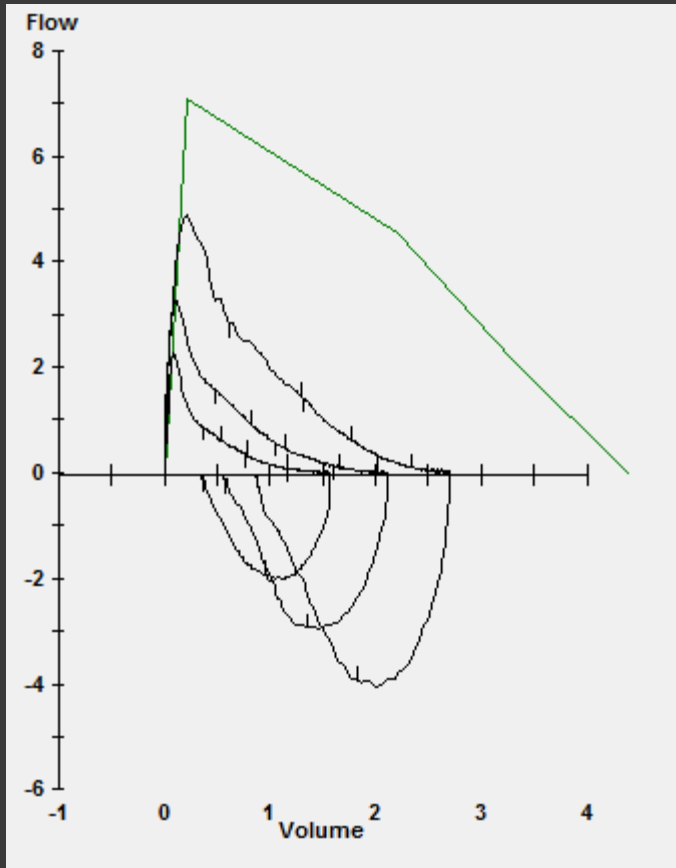


Trial 2



Trial 3

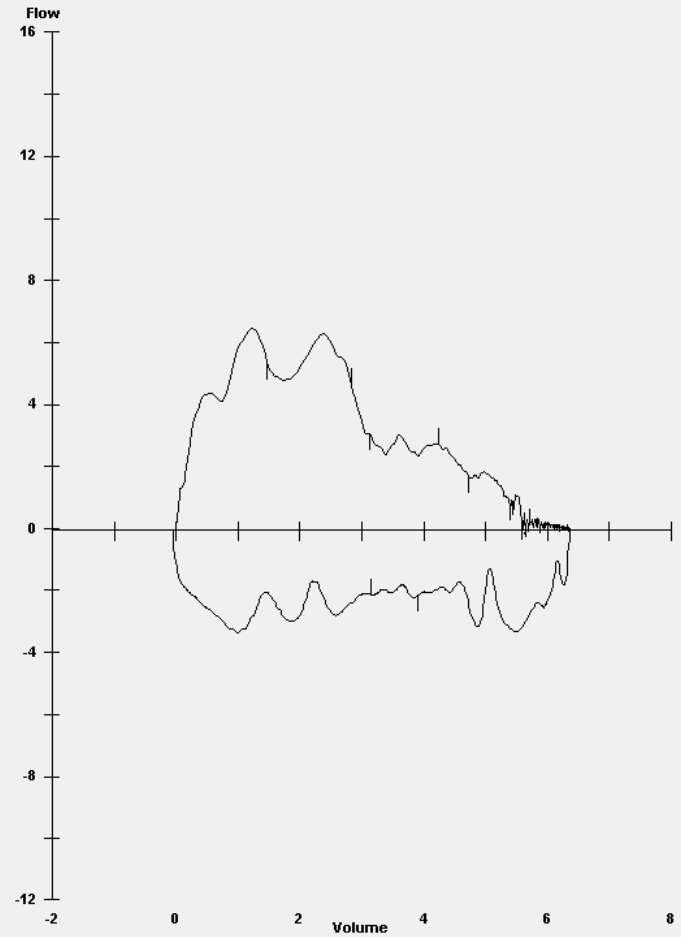
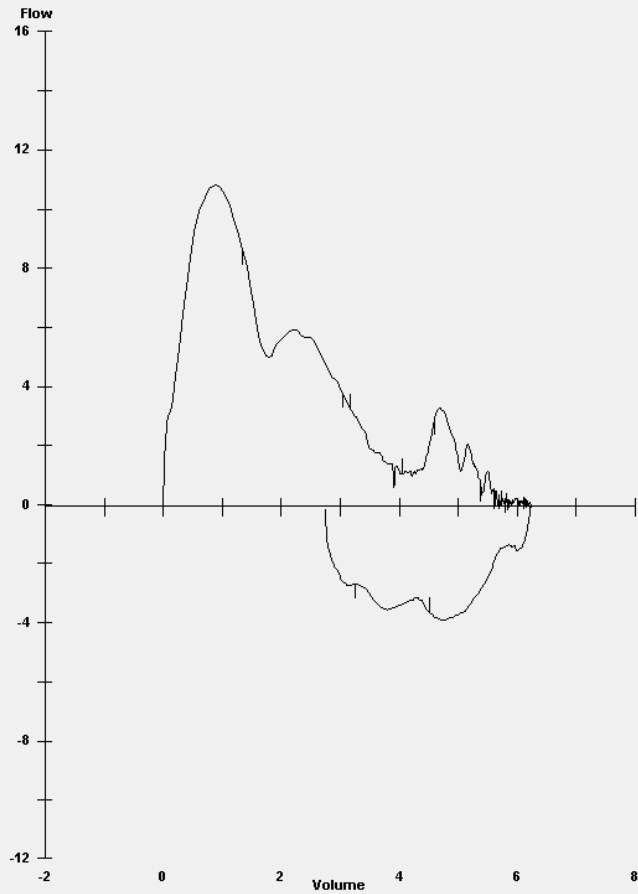




# Spiro Induced Bronchospasms

- ⦿ This does occur, but not often. About 1/200 patients with Asthma.
- ⦿ Not always easily noticed. Often think patient not doing test properly.
- ⦿ Will typically see a decrease in the patients FEV1/FVC ratio.
- ⦿ May be a reason for doing SVC first.

# Problem 9



# Tongue Placement

- ⦿ When the patient's tongue is obstructing the mouthpiece or airway. Can be misleading as patient looks as though they are giving great effort. Causes expiratory stridor.
- ⦿ Ensure patient keeps tongue towards the bottom of their mouth.
- ⦿ Explain to patient like blowing candles on cake.
- ⦿ Instruct patient that you want them blowing out so fast they puff out their cheeks.
- ⦿ If available use tongue depressor mouthpiece.



# Language Barrier

- ⦿ Throw out your script and verbal feedback.
- ⦿ You can explain the basics to interpreter but make sure that patient knows to follow all your actions. Demonstration is even more important.
- ⦿ Do a few blows, no words are necessary. Work on problem areas one at a time. Simple instructions via interpreter.
- ⦿ If no interpreter the biggest problem will be to get the patient to blow out to RV.
- ⦿ For deaf patients, Use hand signals, can also write quick instructions on pad of paper.

# Spirometry: Flow-Volume Curve and Spirogram

