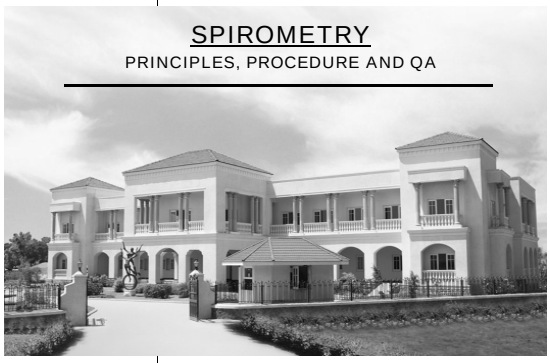
SPIROMETRY

PRINCIPLES, PROCEDURE AND QA



CHEST RESEARCH FOUNDATION, PUNE

Spirometry:

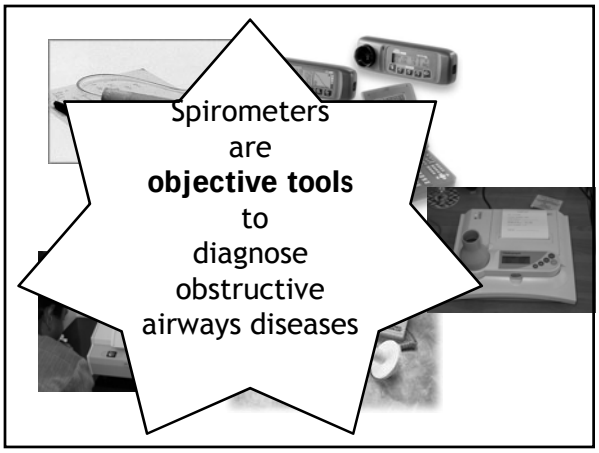
UNDERSTANDING BASICS
HOW TO PERFORM
QUALITY ASSURANCE

Dr. Rahul Kodgule

WHAT IS A SPIROMETER?

- ☐ FEVER
- ☐ ISCHAEMIC HEART DISEASE
- ☐ DIABETES

WHAT IS SPIROMETRY?



BUT WHAT WE PRACTICE:

HOW RELIABLE IS THIS?

- American Study - >20,000 US adults underwent history + clinical examination versus spirometry (1988-1994)
  - If you relied on history and clinical examination to make a diagnosis of OAD, 63.3% remained under-diagnosis
  - Even, 50% of patients with severe OAD were missed

  (NHANES Study, Mannino et al, Arch Int Med 2000; 160: 1683-1689)
- Similar observations in UK, France, Spain and other European countries

  (Huchon, ERJ 2002; Pena, Am J Respir Crit Care Med 2001)

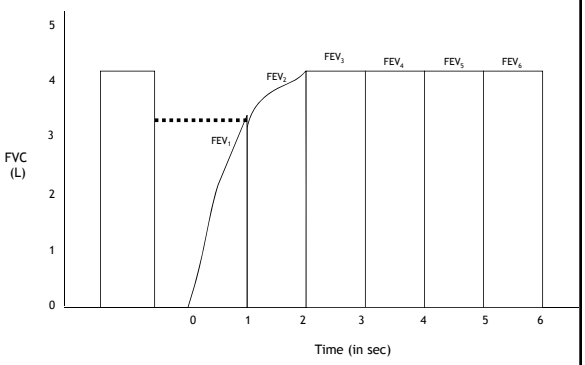
>50% CASES OF OAD REMAIN UNDETECTED IN CLINICAL PRACTICE, IF WE DO NOT USE SPIROMETRY

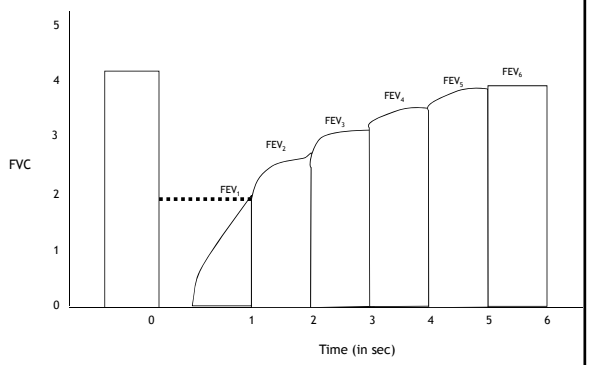
MOST COMMON INDICATION OF SPIROMETRY

Measurement of airflow obstruction

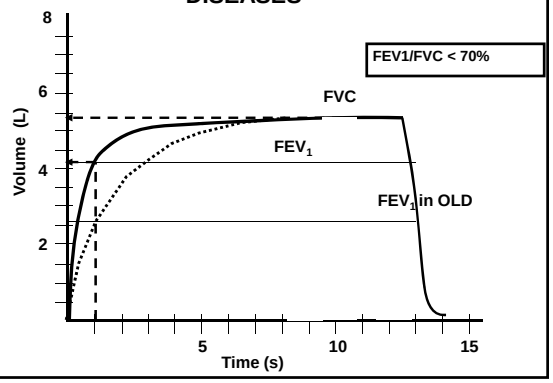
How can you measure airflow obstruction by just blowing into a machine?

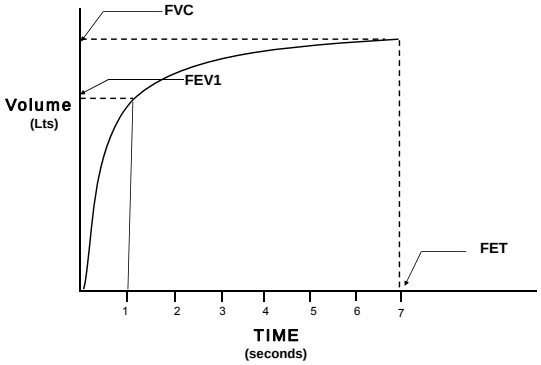
SPIROMETRY

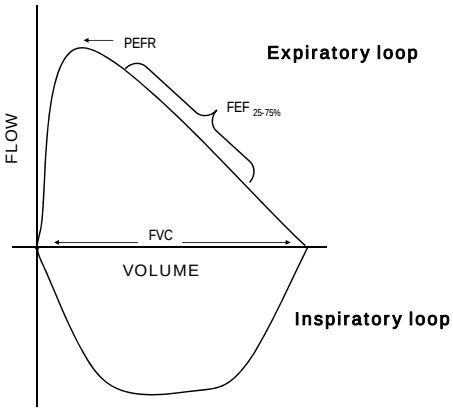




DIAGNOSING OBSTRUCTIVE AIRWAYS DISEASES







WHAT DO WE MEASURE?

ONE RATIO:

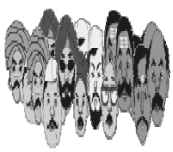
- FEV1/FVC

- TWO VOLUMES:
- 1. FEV1 and
- 2. FVC

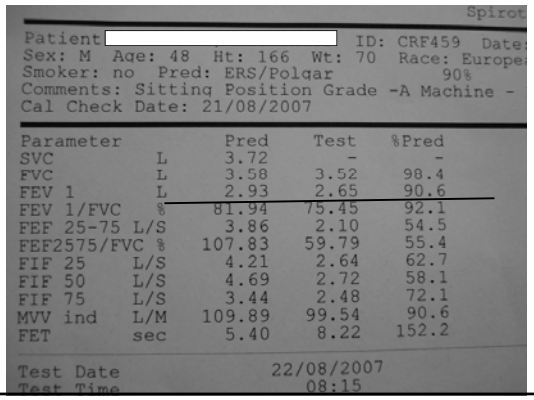
- TWO FLOWS:
- 1. PEAK EXPIRATORY FLOW RATE (PEFR)
- 2. FEF25-75

SO WHAT ARE THE NORMAL VALUES OF THE SPIROMETRIC PARAMETERS

- C Predicted Values
- Age
- Sex
- Height
- Race



CONCEPT OF PREDICTED VALUES



Patient [redacted] ID: CRF459 Date:
Sex: M Age: 48 Ht: 166 Wt: 70 Race: Europe
Smoker: no Pred: ERS/Polgar 90%
Comments: Sitting Position Grade -A Machine -
Cal Check Date: 21/08/2007

Parameter		Pred	Test	%Pred
SVC	L	3.72	-	-
FVC	L	3.58	3.52	98.4
FEV 1	L	2.93	2.65	90.6
FEV 1/FVC	%	81.94	75.45	92.1
FEF 25-75	L/S	3.86	2.10	54.5
FEF2575/FVC	%	107.83	59.79	55.4
FIF 25	L/S	4.21	2.64	62.7
FIF 50	L/S	4.69	2.72	58.1
FIF 75	L/S	3.44	2.48	72.1
MVV ind	L/M	109.89	99.54	90.6
FET	sec	5.40	8.22	152.2

Test Date 22/08/2007
Test Time 08:15

Subject preparation:

Avoid

* Smoking within 1 hr of testing
* Consuming alcohol within 4 hrs
* Vigorous exercise within 30 min
* Large meal within 2 hrs
* Tea /Coffee at least 12 hrs prior to test
* Short acting bronchodilator within 6 hrs

Why withhold drug?

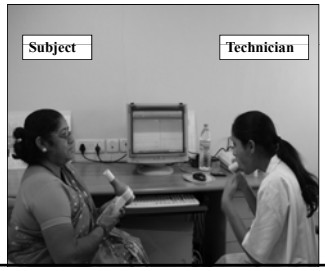
Baseline lung functions
Bronchodilator = false high values.

Drug Withholding Time (hrs)

- Salmeterol / Formoterol - 12 hrs
- Tiotropium - 24 hrs
- Ipratropium - 8 hrs
- Terbutaline - 6 hrs
- Salbutamol - 6 hrs

SUBJECT TRAINING

- ✓ **Explain the procedure to the patient**
- ✓ **Demonstrate the procedure to the patient**
- ✓ **Give 1 or 2 trial runs with the mouth piece**



POSITION OF THE SUBJECT

- ⊙ Sitting or standing
- ⊙ Chair without wheels and having arms
- ⊙ Remove Dentures
- ⊙ Standing preferable for obese, pregnant women & children
- ⊙ Instruct patient to loosen tight fitting clothing
- ⊙ **Elevate chin, extend neck slightly**
- ⊙ Nose clip

Key points

- ☻ Lips must be **sealed** on the mouthpiece correctly
- ☻ Strong effort **right from the start** of the test.
- ☻ Make sure that patient removes every single ml of air from his lungs
- ☻ Patient **must remain upright**.
- ☻ **Reassure** and **encourage** at all times.

PROCEDURE

PHASE - 1

Nice deeeeeeep inhalation

Take a nice deeeeeep breath in…
Fill your chest with as much air as you can

FVC

FEV1

PEFR

FEF25 -75

PHASE - II

Blast

Blow as fast as you can……
Blast maximum……

PEFR, FEV1, FEF_{25-75}

PHASE - III

Continue to remove as much air as possible

FVC

PHASE - IV

Take deep inspiration

(Inspire as much air as was blown out)

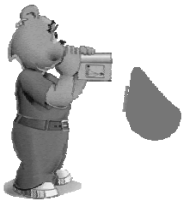
WHEN TO STOP?

1. Patient becomes too breathless to perform the test.
2. Look for
   - Acceptability: Look at curves (both flow-volume & volume-time) and decide
   - Repeatability: Difference between the two best blows for FEV1 and FVC is <5% (around 150ml)
3. At least 3 maneuvers which are acceptable & repeatable should be obtained
4. Maximum - 8 times

   Remember: A poorly performed spirometry increases the risk of misinterpreting results

THE BASICS

Subject Cooperation



Correct Technique

Doctor's Interpretation

IMPORTANT PARAMETERS

Parameter	Definition	Importance
FVC (forced vital capacity)	maximum volume of air which can be exhaled or inspired during either a maximally forced (FVC) or a slow (VC) maneuver	VC is normally equal to FVC unless airflow obstruction is present, in which case VC is usually higher than FVC
FEV1 (forced expired volume in one second)	volume expired in the first second of maximal expiration after a maximal inspiration	useful measure of how quickly full lungs can be emptied
FEV1/FVC	FEV1 expressed as a percentage of the VC or FVC (Normal 70-90%)	gives a clinically useful index of airflow limitation
FEF25-75%	average expired flow over the middle half of the FVC maneuver	sensitive measure of small airways narrowing
PEF (peak expiratory flow)	maximal expiratory flow rate achieved	sensitive measure of large airways narrowing

IMPORTANT PARAMETERS

Parameter	Definition
FVC (forced vital capacity)	maximum volume of air which can be exhaled or inspired during either a maximally forced (FVC) or a slow (VC) maneuver
FEV1 (forced expired volume in one second)	volume expired in the first second of maximal expiration after a maximal inspiration
FEV1/FVC	FEV1 expressed as a percentage of the VC or FVC (Normal 70-90%)
FEF25-75%	average expired flow over the middle half of the FVC maneuver
PEF (peak expiratory flow)	maximal expiratory flow rate achieved

IMPORTANT PARAMETERS

1. **FEV1**
2. **FVC**
3. **FEV1/FVC**
4. **FEF (25-75)**
5. **PEF**

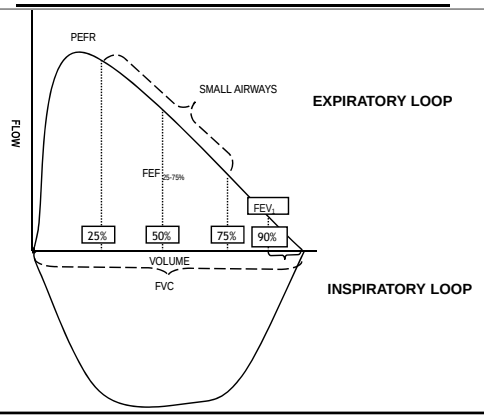
SIGNIFICANCE OF FEV1

- DIAGNOSING OAD
- GRADING SEVERITY
- MONITORING RESPONSE TO TREATMENT

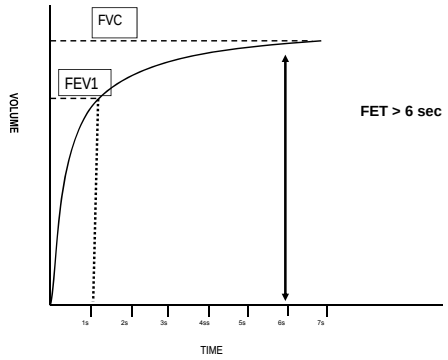
SPIROMETRY GRAPHS

1. **FLOW VOLUME LOOP**
2. **VOLUME TIME GRAPH**

NORMAL FLOW VOLUME LOOP



NORMAL VOLUME TIME LOOP



ACCEPTIBILITY CTITERIA

- Test was initiated from full inspiration
- The test was performed with a rapid start
- A continuous maximal expiratory manoeuvre/effort throughout the test (i.e. no stops and starts) was achieved
- There was no evidence of hesitation, leaks or cough during the test
- The PEF has a sharp rise (peak)
- No glottis closure (Valsalva)
- No obstruction of the mouthpiece (e.g. by the tongue or teeth)
- No evidence that the patient took an additional breath during the expiratory manoeuvre
- No premature termination.(i.e. expiration continued for ≥ 6 seconds)

ATS/ERS CRITERIA

FOR ACCEPTABILITY:

- Should be free from the following artefacts:

- Cough during the first second of exhalation
- Glottis closure that influences the measurement
- Early termination or cut-off
- Effort that is not maximal throughout
- Leak
- Obstructed mouthpiece

Should have good starts:

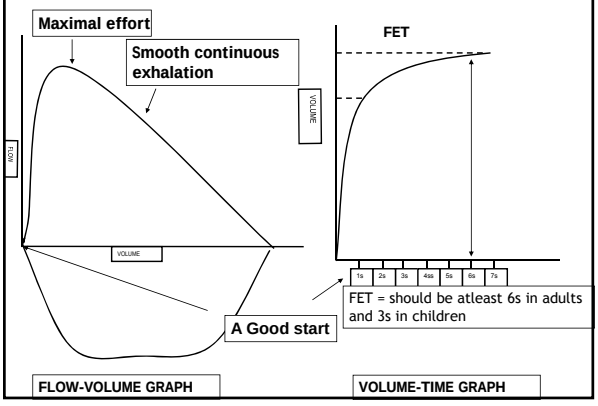
- Extrapolated volume < 5% of FVC or 150 ml, whichever is greater

They should show satisfactory exhalation:

- Duration of ≥ 6 s (3 s for children) or a plateau in the volume-time curve or if the subject cannot or should not continue to exhale

- **REPEATABILITY CRITERIA:**
- The two largest values of FVC must be within 150ml of each other
- The two largest values of FEV1 must be within 150ml of each other
- Save as a minimum, the three acceptable manoevres

Criteria of Acceptability

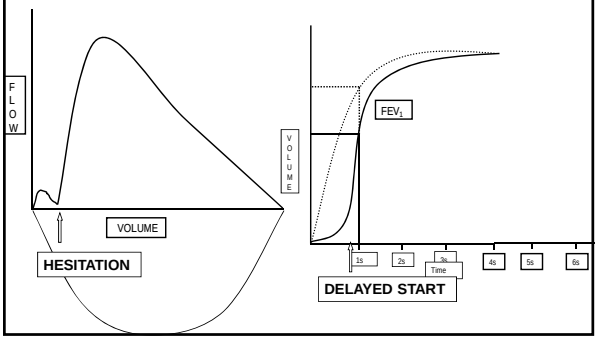


UNACCEPTABLE TEST

- **Inadequate inhalation**
- **Poor Effort**
- **Delayed start**: Excessive hesitation, air leak
- **Coughing:** in the first second or any other cough, which according to technician will, interfere with the measurements
- **Early termination of expiration**: glottis closure, hesitation.
- **Obstruction due to tongue** or teeth.
- **Extra breath taken** in the maneuver
- **Forced expiratory time(FET) less than 6 secs.**

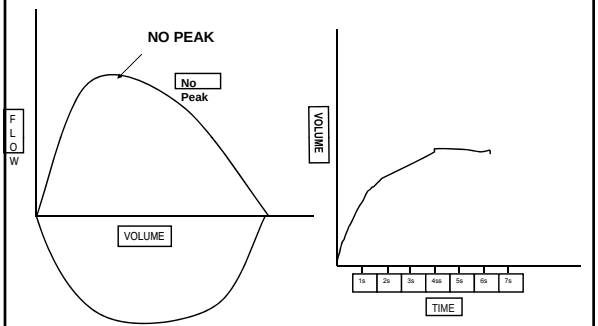
Unsatisfactory Start (Hesitation, air leak, poor effort)

False Low FEV1 readings



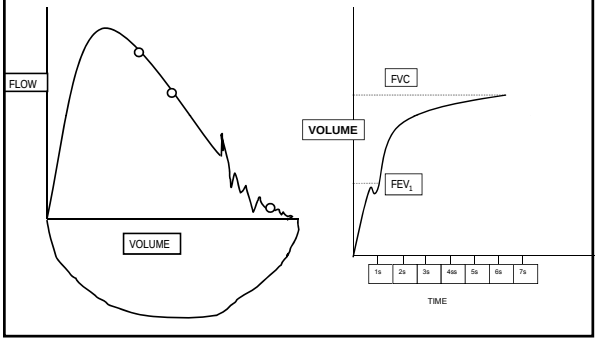
POOR EFFORT

UnreliableFEV1 and FVC



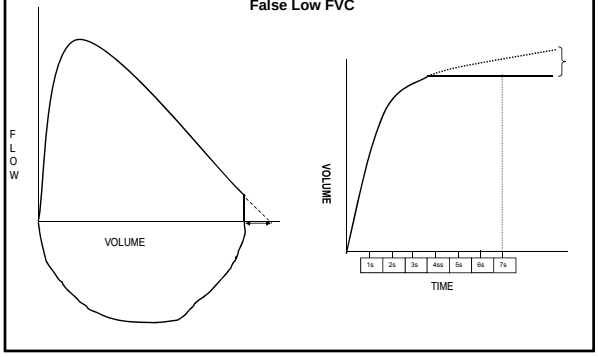
COUGH IN THE FIRST SECOND

Irregularity in the flow in the first second, contributes to wrong FEV_1 readings

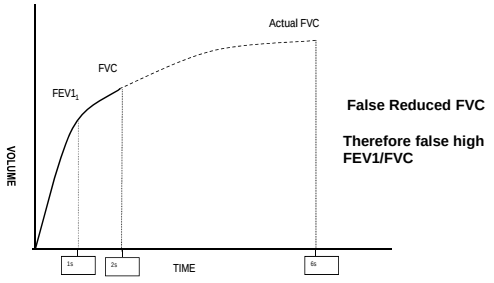


EARLY TERMINATION (Glottis Closure)

False Low FVC



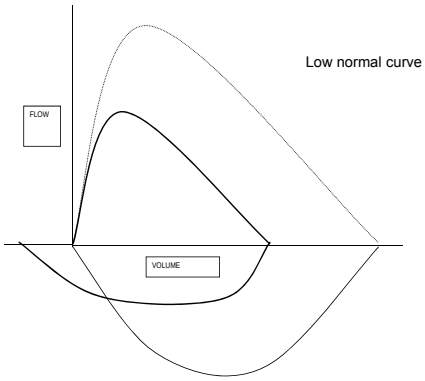
FET<6 seconds



False Reduced FVC

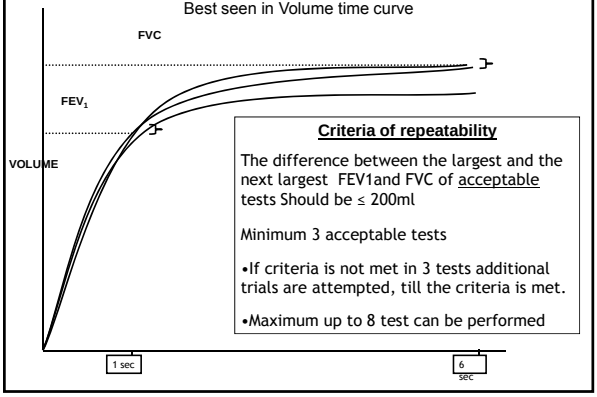
Therefore false high FEV1/FVC

INADEQUATE INHALATION



Repeatability

Best seen in Volume time curve



Criteria of repeatability

The difference between the largest and the next largest FEV1and FVC of acceptable tests Should be ≤ 200ml

Minimum 3 acceptable tests

- If criteria is not met in 3 tests additional trials are attempted, till the criteria is met.
- Maximum up to 8 test can be performed

ATS/ERS CRITERIA

FOR ACCEPTABILITY:

- Should be free from the following artefacts:

- Cough during the first second of exhalation
- Glottis closure that influences the measurement
- Early termination or cut-off
- Effort that is not maximal throughout
- Leak
- Obstructed mouthpiece

Should have good starts:

- Extrapolated volume < 5% of FVC or 150 ml, whichever is greater

They should show satisfactory exhalation:

- Duration of ≥ 6 s (3 s for children) or a plateau in the volume-time curve or if the subject cannot or should not continue to exhale

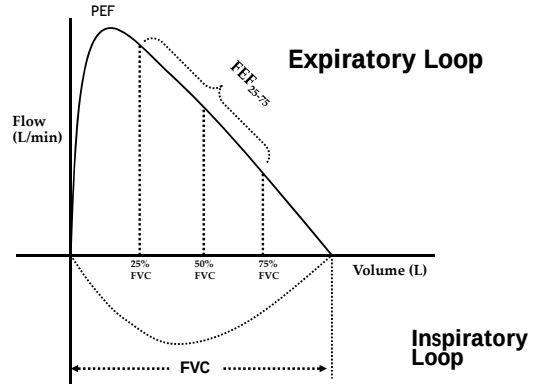
- **REPEATABILITY CRITERIA:**
- The two largest values of FVC must be within 150ml of each other
- The two largest values of FEV1 must be within 150ml of each other
- Save as a minimum, the three acceptable manoevres

INTERPRETATION OF THE GRAPHS

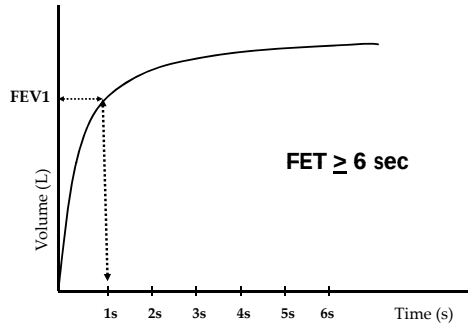
SPIROMETRY GRAPHS

1. **FLOW VOLUME LOOP**
2. **VOLUME TIME GRAPH**

NORMAL FLOW VOLUME LOOP



NORMAL VOLUME TIME LOOP



ACCEPTIBILITY CTITERIA

The inspiration should be adequate.

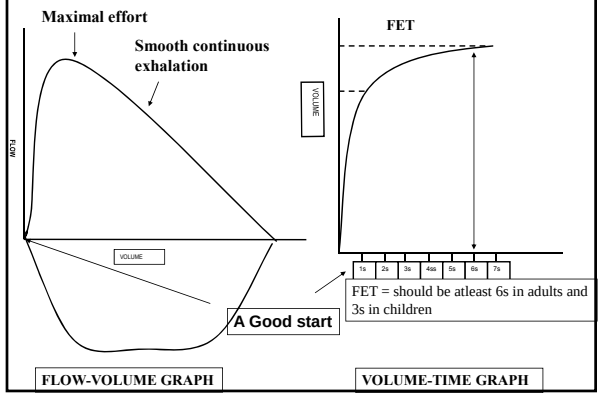
The expiratory effort should be maximal, smooth and cough free.

The test was performed with a rapid start

The PEF has a sharp rise (peak)

The expiration time (FET) was ≥ 6 sec

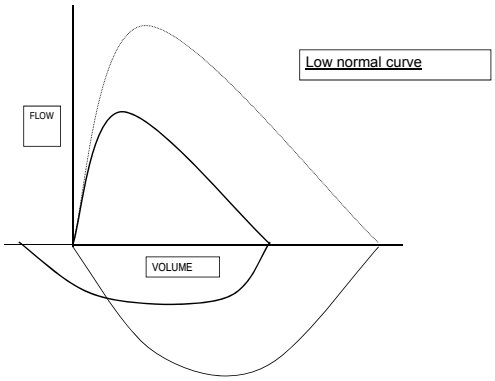
Criteria of Acceptability



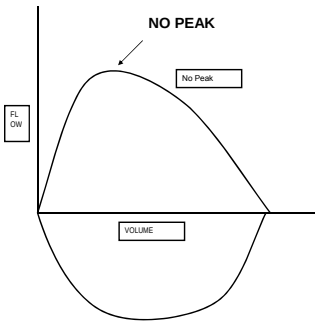
UNACCEPTABLE TEST

- **Forced expiratory time(FET) less than 6 secs.**
- **Inadequate inhalation**
- **Poor Effort**
- **Delayed start**: Excessive hesitation, air leak
- **Coughing:** in the first second or any other cough, which according to technician will, interfere with the measurements
- **Early termination of expiration**: glottis closure, hesitation.

INADEQUATE INHALATION

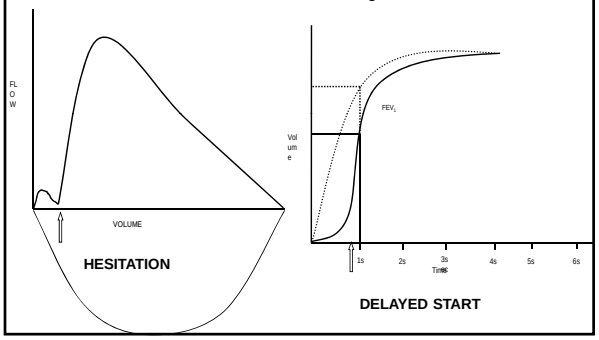


POOR EFFORT



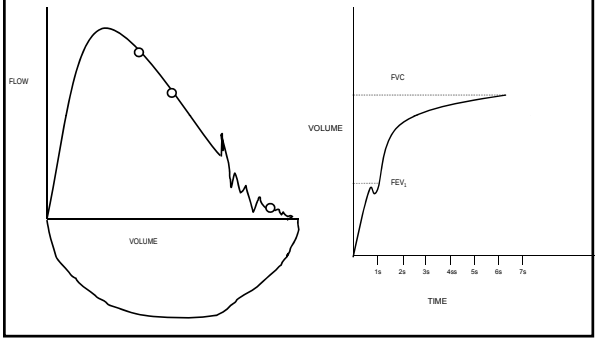
Unsatisfactory Start (Hesitation, air leak, poor effort)

False Low FEV1 readings



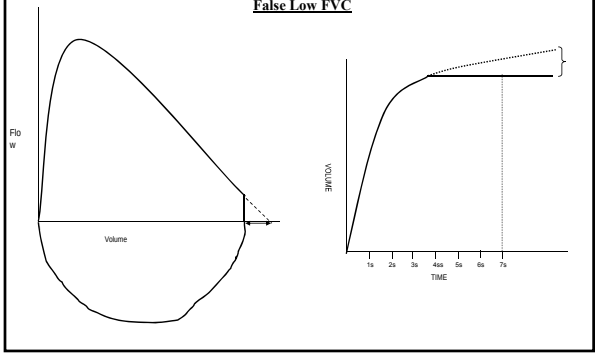
COUGH IN THE FIRST SECOND

Irregularity in the flow in the first second, contributes to wrong FEV_1 readings

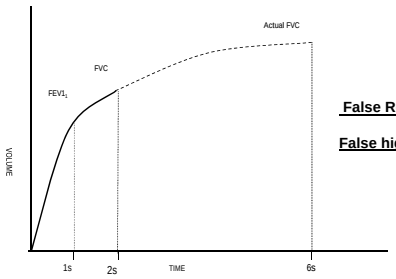


EARLY TERMINATION (Glottis Closure)

False Low FVC



FET<6 seconds

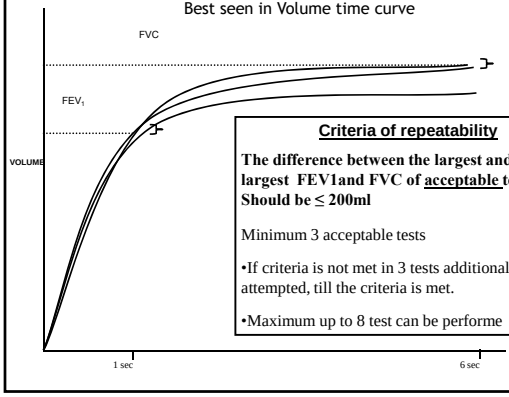


False Reduced FVC

False high FEV1/FVC

Repeatability

Best seen in Volume time curve



Criteria of repeatability

The difference between the largest and the next largest FEV1and FVC of acceptable tests Should be ≤ 200ml

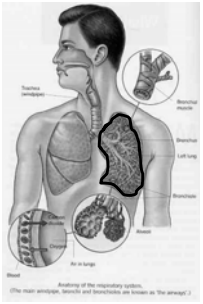
Minimum 3 acceptable tests

•If criteria is not met in 3 tests additional trials are attempted, till the criteria is met.

•Maximum up to 8 test can be performe

SPIROMETRY

APPLICATION IN CLINICAL PRACTICE



Obstructive Airway Diseases

Is there obstruction to flow in the airways?

- Asthma
- COPD
- Bronchiolitis
- Diagnosis
- Determining severity of the disease
- Evaluating response to treatment

FEV1/FVC
FEV1
PEFR
FEF 25-75%

ASTHMA OR COPD?

- **Bronchodilator reversibility test**
  - Baseline FEV1 by spirometry. Administer **200mcg** Salbutamol by inhaled route and then measure **FEV1 after 15-30 mins.**
  - Baseline FEV1. Administer oral steroids for 10 days or inhaled steroids for 4 weeks. Repeat FEV1.

If the FEV1 improves by 12% and 200mL
- 80% chance that this is Asthma
- 20% chance that this is COPD

If the FEV1 does not improve by 12% and 200mL
- 80% chance that this is COPD
- 20% chance that this is Asthma

CLASSIFYING ASTHMA & COPD SEVERITY

(Using FEV1 % predicted values)

ASTHMA	60 - 80 rule
COPD	30 – 50 – 80 rule

Pharmacotherapy guidelines for Asthma and COPD are based on severity of the disease

COPD: If FEV1 < 60% predicted – Start inhaled corticosteroids

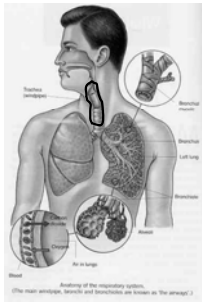
EVALUATE RESPONSE TO TREATMENT

Is my asthma or COPD getting better doctor?

Objective evaluation of response to treatment – using FEV1, FVC, PEFR and FEF25-75% parameters.

SPIROMETRY

APPLICATION IN CLINICAL PRACTICE

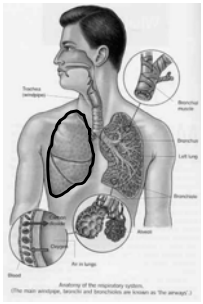


Obstruction in the large airways

- Extrathoracic / Intrathoracic
- Laryngeal / tracheal tumors / stenosis
- Extrinsic tracheal compression

Visual inspection of the Flow-Volume Loop

SPIROMETRY
APPLICATION IN CLINICAL PRACTICE



Restrictive Lung Disorders

Is there a restriction to lung expansion?

- Interstitial Lung Disease
- Pleural disorders
- Musculoskeletal disorders

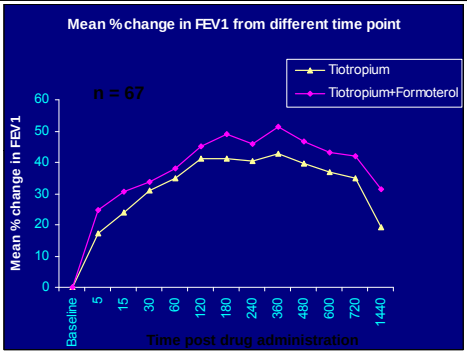
- Diagnosis
- Determining severity of the disease
- Evaluating response to treatment

FEV1/FVC
FVC

SPIROMETRY - OTHER APPLICATIONS

- Patient presenting with breathlessness – Pulmonary/Cardiac
- Diagnosis of Occupational Lung Disease
- Pre-operative evaluation for surgery of thorax or abdomen
- Screening high risk populations (e.g. smokers, pre-employment in industries in which occupational asthma is prevalent)

SPIROMETRY – STUDY EFFICACY OF DRUGS



CRF Pune, 2005

THANK YOU