Spirometry: Introduction

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GMC

Introduction

- Valuable clinical tool
  - Not difficult to master
  - Not difficult to interpret
  - Clinically relevant
- Can you properly manage respiratory conditions without a spirometer?
- Can you properly manage hypertension without a sphygmomanometer?

Spirometry

- Spirometry is a method of assessing lung function by measuring the volume of air the patient can expel from the lungs after a maximal expiration.
- Conventionally, a spirometer is a device used to measure timed expired and inspired volumes,
- From these we can calculate how effectively and how quickly the lungs can be emptied and filled.

Objectives of Spirometry

Diagnosis

- Screening for persons at risk of having pulmonary disease.
- Evaluating symptoms of respiratory impairment
- Pre-op assessment
- Pre-employment screening

Monitoring

- Occ Health: monitor those exposed to hazardous agents
- Determine effectiveness of medication
- Monitor for adverse reactions of other drugs e.g. chemotherapy
- Follow the course of disease – helps predict mortality and morbidity.

Disability and Impairment

- Assessing changes during respiratory rehab
- Insurance risk
- Employment/environmental risk

Research

- Large population studies - predicted (reference equations),
- Pharmaceutical trials

The ABCs of Spirometry:

- **A**ccuracy of the machine
- Correct **B**reathing manoeuvre
  - "Coach"
  - Patient
- **C**orrect clinical interpretation
- **D**ependability of results
  - Reproducibility

Who shouldn't have a spirometry done?

- Late pregnancy
- Recent Eye, Thoracic or Abdominal Surgery
- Abdominal pathology
  - AAA
  - Hernia
- Recent Myocardial Infarction

Additional cautions

- Hypoxia
- Hypotension
- Hyperventilation
- Inability to perform the test

Potential hazards

- Pneumothorax
- Dizziness, light-headedness
- Chest pain
- Cough
- Bronchospasm

Types of Spirometers

- *Bellows spirometers:*
  Measure volume; mainly in lung function units
- *Electronic desk top spirometers:*
  Measure flow and volume with real time display
- *Small hand-held spirometers:*
  Inexpensive and quick to use with / without print out

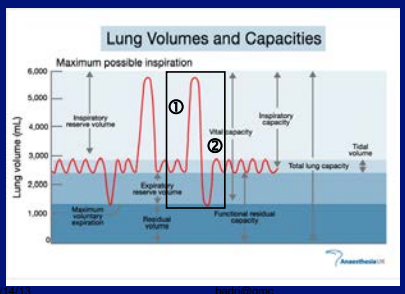
Volume Measuring Spirometer

Flow Measuring Spirometer

Desktop Electronic Spirometers

Small Hand-held Spirometers

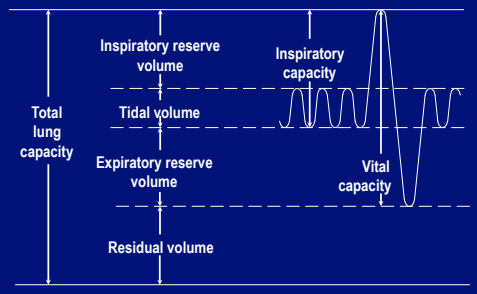
RESPIRATORY MANOEUVRE



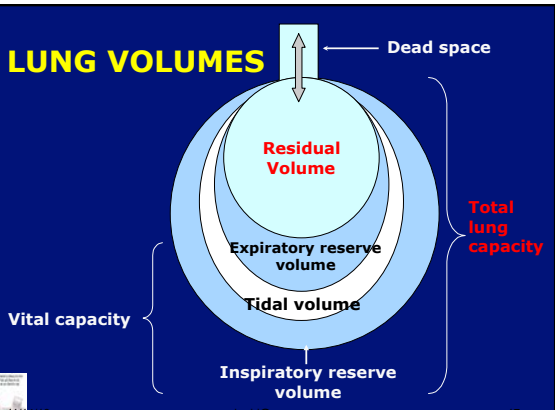
① Maximal breath in

② Maximal breath out

Lung Volume Terminology



LUNG VOLUMES



Standard Spirometric Indicies

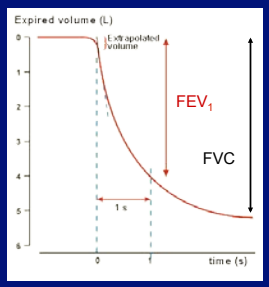
- FEV_1 - The volume of air expired in the first second of the blow
- FVC - The total volume of air that can be forcibly exhaled in one breath
- FEV_1/FVC *ratio:* The fraction of air exhaled in the first second relative to the total volume exhaled
- FER (FEV1/FVC): Forced expiratory Ratio
- PEF*: Peak Expiratory Flow*

Additional Spirometric Indicies

- VC - A volume of a full breath exhaled in the patient's own time and not forced. Often slightly greater than the FVC, particularly in COPD
- FEV_6 – Often approximates the FVC. Easier to perform in older and COPD patients but role in COPD diagnosis remains under investigation
- MEFR (FEF 25-75) – *Mid-expiratory flow rates:* Derived from the mid portion of the flow volume curve but is not useful for COPD diagnosis

FEV_1 & FVC

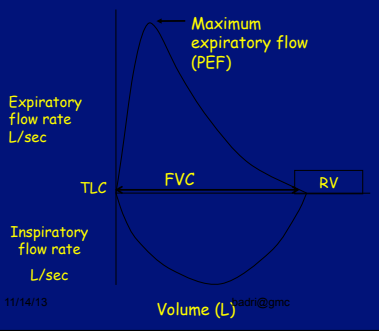
- Forced expiratory volume in 1 second
  - 4.0 L
- Forced vital capacity
  - 5.0 L
  - usually less than during a slower exhalation
- FEV_1/FVC = 80%



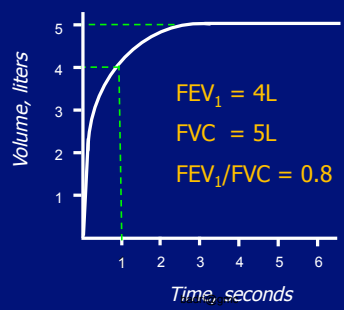
Flow Volume Curve

- Standard on most desk-top spirometers
- Adds more information than volume time curve
- not difficult to interpret
- Better at demonstrating mild airflow obstruction

Flow Volume Curve



Normal Trace Showing FEV_1 and FVC



Techniques

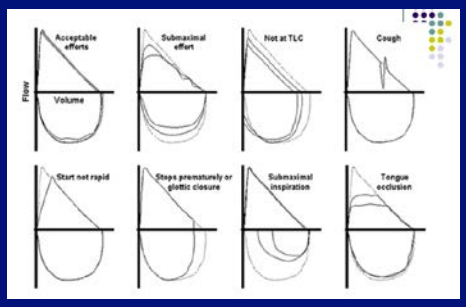
Correct Technique 1
- Maximum inspiration
- Tight seal around mouthpiece
- Forceful and complete expiration

Correct Technique 2
- Input patient data prior to test
- Last bronchodilator?
- Disposable mouthpiece with filter
- ? Nose peg
- Chair behind patient

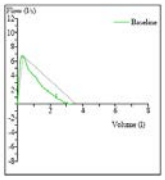
Correct Technique 3
- Special Circumstances
  - Empty Bladder
  - Remove Dentures

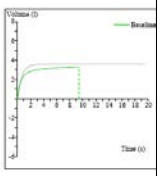
Common Pitfalls

- Incomplete Inspiration
- Poor seal
- Sub-maximal effort
  - Commencement
  - Terminal
- Cough
- Posture
- Adequate recovery time



Acceptability





Example of an acceptable test.
Smooth take-off without hesitation or coughing
Graphs smooth – no irregularity
1 sec plateau at end of test
Minimum 6 sec exhalation

Rapid upslope
Smooth down slope
Complete expiration

"Normal Values" 1

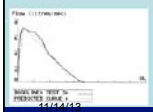
- Gender
- Age
- Height
- Ethnic Origin:
  - Caucasians 15% greater FEV1 and FVC

Normal Values 3

- FEV1> 80%
- FVC > 80%
- FER > 70%
  - Note that the actual FER is the important reading not the predicted value
- PEF > 80%

Normal Values 2

- 59 y. o. male
  Caucasian height 178



	Result
FEV1	3.55
FVC	4.30
FER	82.5%
PEF	600

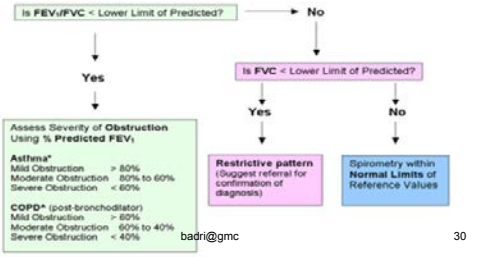
Normal Values 4

	Actual	Predicted	%Predict	Range
FEV1	3.55	3.45	102%	2.6-4.3
FVC	4.30	4.37	98%	3.4-5.4
FER	82.5%	76.5%		
PEF	600	512	117%	398-636

Summary of Standards

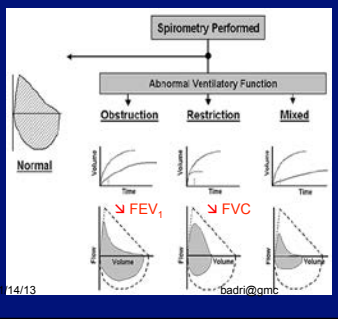
- A min. of **3 technically satisfactory tests.**
- A max. of **8 attempts.**
- The two best FVC and FEV1's should have a variance of less than **150mls.**
- Exhaled for at least 6 seconds (adults) or reached a plateau on the volume-time graph. (No change of volume for at least one second.)
- Graph traces are smooth and free from irregularity--Smooth take-off without hesitation

Flow Chart



FLOW-VOLUME CURVE

in respiratory patients



- Restrictive disease
  - ↘ expansion of the lung
  - e.g., interstitial fibrosis
- Obstructive disease
  - ↗ resistance to airflow
  - e.g., COPD, asthma

Bronchodilator Reversibility Testing

- Provides the best achievable FEV_1 (and FVC)
- Helps to differentiate COPD from asthma

Must be interpreted with clinical history - neither asthma nor COPD are diagnosed on spirometry alone

Bronchodilator Reversibility Testing

- Can be done on first visit if no diagnosis has been made
- Best done as a planned procedure: pre- and post-bronchodilator tests require a minimum of 20 minutes
- Post-bronchodilator only saves time but does not help confirm if asthma is present
- Short-acting bronchodilators need to be withheld for at least 4 hours prior to test

Bronchodilator Reversibility Testing

Bronchodilator*	Dose	FEV_1 before and after
Salbutamol	200 – 400 µg via large volume spacer	15 minutes
Terbutaline	500 µg via Turbohaler®	15 minutes
Ipratropium	160 µg** via spacer	45 minutes

* Some guidelines suggest nebulised bronchodilators can be given but the doses are not standardised. "There is no consensus on the drug, dose or mode of administering a bronchodilator in the laboratory." Ref: ATS/ERS Task Force : Interpretive strategies for Lung Function Tests *ERJ* 2005;26:948

** Usually 8 puffs of 20 µg

Bronchodilator Reversibility Testing in COPD

Figure 5.1-6. Bronchodilator Reversibility Testing in COPD

Preparation

- Tests should be performed when patients are clinically stable and free from respiratory infection.
- Patients should not have taken inhaled short-acting bronchodilators in the previous six hours, long-acting bronchodilator in the previous 12 hours, or sustained-release theophylline in the previous 24 hours.

Spirometry

- FEV_1 should be measured before a bronchodilator is given.
- The bronchodilator should be given by metered dose inhaler through a spacer device or by nebulizer to be certain it has been inhaled.
- The bronchodilator dose should be selected to be high on the dose/response curve.
- Possible dosage protocols are 400 µg β_2-agonist, up to 160 µg anticholinergic, or the two combined[20]. FEV_1 should be measured again 10-15 minutes after a short-acting bronchodilator is given; 30-45 minutes after the combination.

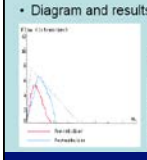
Results

- An increase in FEV_1 that is both greater than 200 ml and 12% above the pre-bronchodilator FEV_1 is considered significant[20]. It is usually helpful to report the absolute change as well as the % change from baseline to set the improvement in a clinical context.

GOLD Report (2006)

Reversibility Testing 2

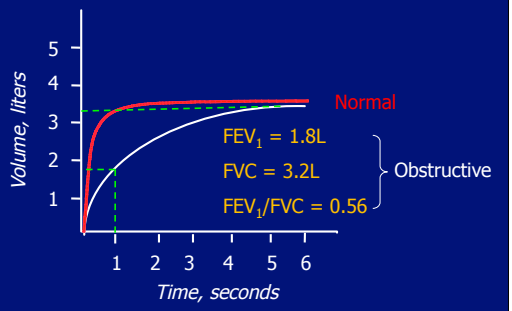
- Diagram and results



Interpretation of results 2

	FEV1	FVC	FER
Normal	>80%	>80%	>70%
Restrictive	>80%	<80%	>70%
Obstructive		>80%	<70%
Mixed	<80%	<80%	<70%

Spirometry: Obstructive Disease



Diseases Associated With Airflow Obstruction

- COPD
- Asthma
- Bronchiectasis
- Cystic Fibrosis
- Post-tuberculosis
- Lung cancer (greater risk in COPD)
- Obliterative Bronchiolitis

Spirometric Diagnosis of COPD

- COPD is confirmed by post–bronchodilator $FEV_1/FVC < 0.7$
- Post-bronchodilator FEV_1/FVC measured 15 minutes after 400µg salbutamol or equivalent

COPD classification based on spirometry

GOLD 2003

Severity	Postbronchodilator FEV_1/FVC	Postbronchodilator FEV_1% predicted
At risk	>0.7	≥80
Mild COPD	≤0.7	≥80
Moderate COPD	≤0.7	50-80
Severe COPD	≤0.7	30-50
Very severe COPD	≤0.7	<30

SPIROMETRY is not to substitute for clinical judgment in the evaluation of the severity of disease in individual patients.

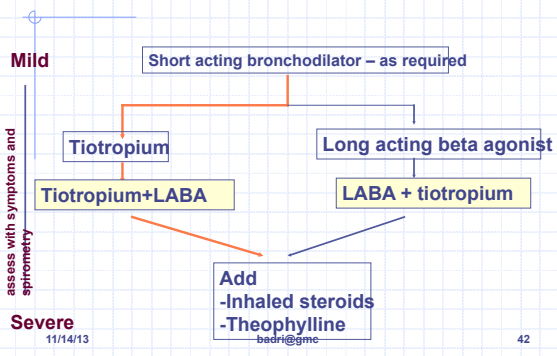
Management based on GOLD

Stage (2003 update)	0 At risk	I Mild	II Moderate	III Severe	IV Very severe
Post-bronchodilator FEV1 (% predicted)	Normal	>80%	50–80%	30–50%	<30%

- Avoidance of risk factors **SMOKING CESSATION**
- Influenza vaccination
- Short-acting bronchodilator if needed
- Add regular treatment with one or more long-acting bronchodilators, including tiotropium
- Pulmonary rehabilitation
- Add regular treatment with inhaled corticosteroids if repeated exacerbations
- Long-term oxygen therapy (LTOT) if respiratory failure
- Consider surgical options

Based on GOLD global strategy (2003)

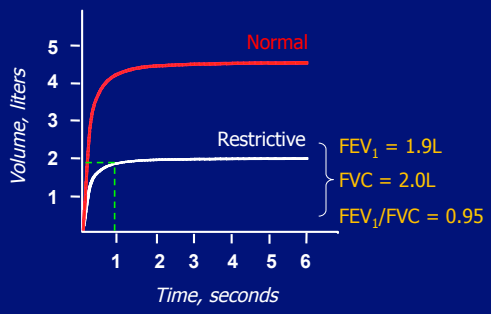
Algorithm for the management of COPD



Criteria: Restrictive Disease

- $FEV_{1:}$ % predicted < 80%
- FVC: % predicted < 80%
- FEV_1/FVC: > 0.7

Spirometry: Restrictive Disease



Diseases Associated with a Restrictive Defect

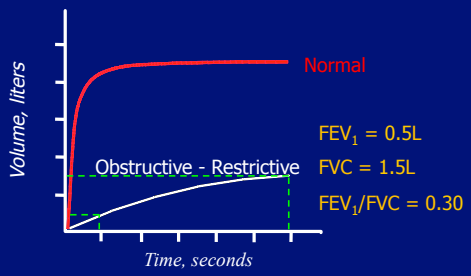
Pulmonary
- Fibrosing lung diseases
- Pneumoconioses
- Pulmonary edema
- Parenchymal lung tumors
- Lobectomy or pneumonectomy

Extrapulmonary
- Thoracic cage deformity
- Obesity
- Pregnancy
- Neuromuscular disorders
- Fibrothorax

Mixed Obstructive/Restrictive

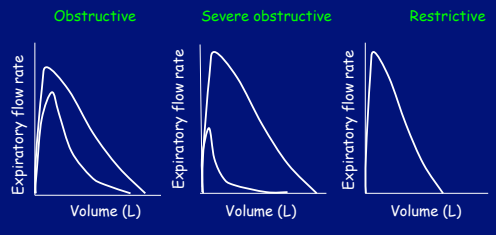
- FEV_1: % predicted < 80%
- FVC: % predicted < 80%
- FEV_1/FVC: < 0.7

Mixed Obstructive and Restrictive



Restrictive and mixed obstructive-restrictive are difficult to diagnose by spirometry alone; full respiratory function tests are usually required (e.g., body plethysmography, etc)

Flow Volume Curve Patterns Obstructive and Restrictive

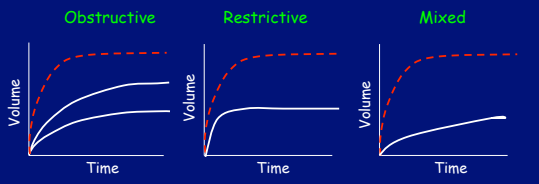


Reduced peak flow, scooped out mid-curve

Steeple pattern, reduced peak flow, rapid fall off

Normal shape, normal peak flow, reduced volume

Spirometry: Abnormal Patterns



Slow rise, reduced volume expired; prolonged time to full expiration

Fast rise to plateau at reduced maximum volume

Slow rise to reduced maximum volume; measure static lung volumes and full PFT's to confirm

Summary

	Obstruction	Restriction	Mixed
FEV1	↓	↓ or normal	↓
FVC	↓ or normal	↓	↓
FEV1/FVC	↓	↑ or normal	↓

BRONCHIAL PROVOCATION TESTS

- Exposure of the airways to a **stimulus**
  - allergen
  - exercise
  - pharmacological bronchoconstrictive agent
- **Response of the smooth muscle ?**
  - baseline FEV_1
  - post-exposure FEV_1

➢ Airway hyperresponsiveness

The END

PRACTICAL SESSION

Performing Spirometry

Spirometry Training

- Training is essential for operators to learn correct performance and interpretation of results
- Training for competent performance of spirometry requires a minimum of 3 hours
- Acquiring good spirometry performance and interpretation skills requires practice, evaluation, and review
- Spirometry performance (who, when and where) should be adapted to local needs and resources
- Training for spirometry should be evaluated

Obtaining Predicted Values

- Independent of the type of spirometer
- Choose values that best represent the tested population
- Check for appropriateness if built into the spirometer

Optimally, subjects should rest 10 minutes before performing spirometry

Withholding Medications

Before performing spirometry, withhold:

- ✓ Short acting β_2-agonists for 6 hours
- ✓ Long acting β_2-agonists for 12 hours
- ✓ Ipratropium for 6 hours
- ✓ Tiotropium for 24 hours

Optimally, subjects should avoid caffeine and cigarette smoking for 30 minutes before performing spirometry

Performing Spirometry - Preparation

1. Explain the purpose of the test and demonstrate the procedure
2. Record the patient's age, height and gender and enter on the spirometer
3. Note when bronchodilator was last used
4. Have the patient sitting comfortably
5. Loosen any tight clothing
6. Empty the bladder beforehand if needed

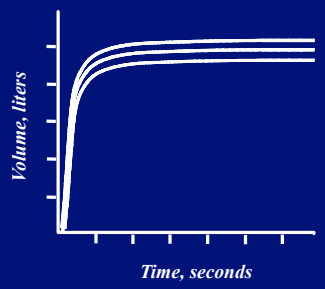
Performing Spirometry

- Breath in until the lungs are full
- Hold the breath and seal the lips tightly around a clean mouthpiece
- Blast the air out as forcibly and fast as possible. Provide lots of encouragement!
- Continue blowing until the lungs feel empty

Performing Spirometry

- Watch the patient during the blow to assure the lips are sealed around the mouthpiece
- Check to determine if an adequate trace has been achieved
- Repeat the procedure at least twice more until ideally 3 readings within 100 ml or 5% of each other are obtained

Reproducibility - Quality of Results



Three times FVC within 5% or 0.1 litre (100 ml)

Spirometry - Possible Side Effects

- Feeling light-headed
- Headache
- Getting red in the face
- Fainting: reduced venous return or vasovagal attack (reflex)
- Transient urinary incontinence

Spirometry should be avoided after recent heart attack or stroke

Spirometry - Quality Control

- Most common cause of inconsistent readings is poor patient technique
  - ✓ Sub-optimal inspiration
  - ✓ Sub-maximal expiratory effort
  - ✓ Delay in forced expiration
  - ✓ Shortened expiratory time
  - ✓ Air leak around the mouthpiece
- Subjects must be observed and encouraged throughout the procedure

Spirometry – Common Problems

- ✓ Inadequate or incomplete blow
- ✓ Lack of blast effort during exhalation
- ✓ Slow start to maximal effort
- ✓ Lips not sealed around mouthpiece
- ✓ Coughing during the blow
- ✓ Extra breath during the blow
- ✓ Glottic closure or obstruction of mouthpiece by tongue or teeth
- ✓ Poor posture – leaning forwards

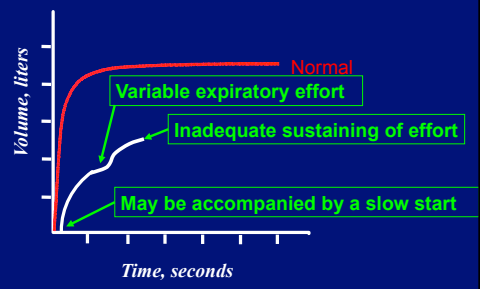
Equipment Maintenance

- Most spirometers need regular calibration to check accuracy
- Calibration is normally performed with a 3 litre syringe
- Some electronic spirometers do not require daily/ weekly calibration
- Good equipment cleanliness and anti-infection control are important; check instruction manual
- Spirometers should be regularly serviced; check manufacturer's recommendations

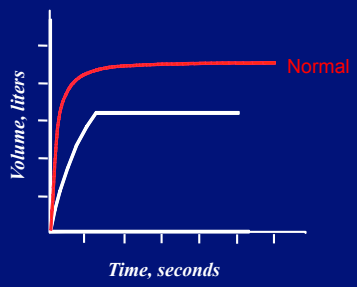
Troubleshooting

Examples - Unacceptable Traces

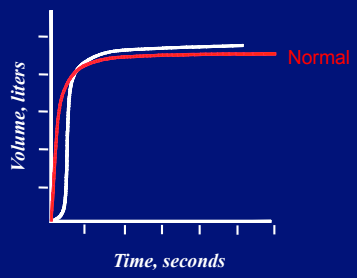
Unacceptable Trace - Poor Effort



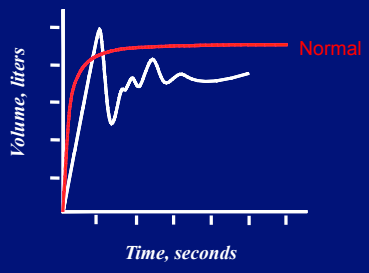
Unacceptable Trace – Stop Early



Unacceptable Trace – Slow Start



Unacceptable Trace - Coughing



Unacceptable Trace – Extra Breath