Spirometry workshop

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History

• Borelli, 1679 – first measured volume of air that a man can inhale in a single breath
• Hutchinson, 1846 – defined vital capacity as the “greatest expiration following the deepest inspiration”, designed spirometer to measure this but not accepted and died in obscurity!
• Rohrer, 1915 – looked at relationship between respiratory muscle force and rate of airflow.
• Peabody, 1915 – examined the relationship between vital capacity and breathlessness.

The most common tests that we perform today are based on these early works.
What are we measuring?

- Lung volumes
- Resistance to airflow

In the lung function laboratory we can also assess gas transfer and residual volumes.
What tests can we perform outside the laboratory?

• Peak flow
• Spirometry
Peak flow

• Measures how quickly air can be expelled from the airways
• Measured within the first 100 milliseconds (10\textsuperscript{th} of a second)
• Index of resistance to flow through the larger airways, bronchi and larger bronchioles

Individuals with bronchial hypersensitivity are subject to reflex broncho-constriction in these airways. Peak flow is an effort dependant test.
Interpretation of peak flow

Reduced peak flow
• Upper airway obstruction e.g. Bronchial Ca, goitre.
• Obstructive airways disease e.g. asthma, COPD
• Advanced restrictive lung disease e.g. UIP, FA
• Chest wall abnormalities e.g. scoliosis, neuromuscular disease

Normal peak flow
• Normal airways!
• Well controlled or stable asthma
• Mild COPD and asymptomatic smokers
• Early restrictive lung disease (Can sometimes be raised)
Why do we do peak flows?

• For diagnostic purposes
  – Comparison to normal/predicted values
  – Reversibility testing – bronchodilator and corticosteroid
  – Peak flow diaries – diurnal variation and serial peak flows
  – Exercise challenge tests

• To monitor control of asthma
  – Prn monitoring
Why do spirometry?

- More informative than peak flow
- To detect presence or absence of lung disease where there is a history or pulmonary symptoms
- To confirm findings of other investigations e.g. chest x-ray or blood gasses
- To establish extent of lung impairment in respiratory disease and monitor progression e.g. COPD / Fibrosis
- To investigate impact of other diseases on lung function e.g. cardiac disease or neuromuscular disease
- Occupational / environmental monitoring e.g. smokers, dust, asbestos
- To determine effects of an intervention e.g. bronchodilator reversibility tests
Spirometry cannot -

- Define the full extent of the disease e.g. In COPD many systemic as well as pulmonary effects
- Define the response to therapy
- Define the extent of disability that the patient experiences
Preparing equipment

• Which Spirometer? Pro’s and cons!
  – Microlabs
  – Vitalograph (alphas)
  – Hand held etc (?screening)

• Storage

• Calibration

• Servicing

• Cleaning and infection control
Preparing the patient

• Letter to invite for test?
• What information do you need?
• Checklist?
Patient preparation

Who should not perform spirometry?

- Recent eye surgery
- Recent MI
- Recent CVA or other cerebral event
- Any recent surgery
- Any others?
Patient preparation

• Record patients date of birth, height, ethnic origin
• Note if the patient is currently unwell or has had a recent exacerbation
• Ensure the patient is comfortable
• Sit the patient in a chair with arms
• Explain the purpose of the test
• You may need to demonstrate the correct technique
• Allow the patient practice attempts
Patient preparation

Before arrival

• No large meal within 2 hours
• No vigorous exercise within half an hour
• Comfortable loose clothing
• Empty bladder
• ?false teeth
Patient preparation

To withhold or not to withhold medication?

If you are doing reversibility testing:
• No short acting bronchodilators for 4 hours
• No long acting bronchodilators for 12 hours
• No sustained release oral bronchodilators for 24 hours

For routine monitoring of COPD patients:
• Take all medication as usual - measure post bronchodilator.
Lung volume terminology

- Tidal volume
- Inspiratory capacity
- Inspiratory reserve volume
- Expiratory reserve volume
- Vital capacity
- Residual volume
Terminology

VC - Vital capacity, the total amount of air that can be expelled from the lungs from full inspiration to full expiration

FVC - Forced vital capacity, should be the same volume as VC but is sometimes reduced due to air trapping in COPD

FEV$_1$ - Forced expiratory volume in one second from full inspiration

FEV$_1$/FVC or FEV$_1$% or FEV$_1$/FVC ratio - The percentage of the FVC that is produced in the first second

FEV$_1$/VC - The percentage of the VC that is produced in the first second
Explaining to the patient

Keep it simple –

“I want to test the amount of air in your lungs and how well or quickly it moves”

Don’t blind the patient with science
Nose clips and mouthpieces

- Nose clips – helpful when patient learning technique to encourage mouth breathing – patient can also pinch own nose. Well-practiced patient may not need nose clips.
- Mouthpiece – should be behind the teeth and on top of the tongue
Measuring vital capacity (VC)

The VC is a non forced measurement. It is often measured at the start of a session.

- Patient breathes in as deeply as is comfortable
- Seals lips around mouthpiece
- Breathes out steadily at a comfortable pace
- Continue until expiration complete
- May need a nose clip
- Repeat
Role of the operator

Demonstrate to the patient
Observe the patient – many operators have a compulsion to watch the paper or screen as the patient is blowing – THIS IS TO BE AVOIDED!!

Watch for technique, leaks and effort.
Stop the test if the patient looks unwell, faint or pale.
Encourage to keep blowing.
Measuring FEV\textsubscript{1} and FVC

- Ask the patient to take a deep breath in – full inspiration
- Patient to blow out forcibly, as hard and fast as possible, until there is nothing left to dispell
  - Encourage patient to keep blowing
  - For some COPD patients this can take up to 15 seconds!
  - Spirometer may bleep to say manoeuvre complete
- Repeat the procedure twice or until reproducible results

“I want you to take as deep a breath in as you can, place the mouthpiece in your mouth and force the air out as hard and fast as you possibly can, until there is no more air to come out”
Maintaining accuracy

The most common reason for inaccurate results is patient technique

Common problems include:

- Inadequate or incomplete inhalation
- Additional breath taken during manoeuvre
- Lips not sealed around mouthpiece
- A slow start to the forced exhalation
- Some exhalation through the nose
- Coughing
Interpretation of results

- Take the best of the 3 consistent readings of $\text{FEV}_1$ and of $\text{FVC}$
- Find the predicted normals for your patient – Your machine may do this for you!
- Get out your calculators!!
Predicted Normals

Depends on:
- Age
- Sex
- Height
- Race
Predicted Normal values

- Based on large population surveyse.g. ERS93, ECCS83
- Predicted values are the mean values obtained from the survey
- No surveys conducted in elderly populations
Normal ventilatory function

• FVC  80 – 120% of predicted

• FEV1  80 – 120% of predicted

• FEV1/FVC ratio >70%
To calculate % predicted

Actual Measurement $\times 100$
Predicted Value

- e.g. Actual FEV1 $= 4.0$ litres
  Predicted FEV1 $= 4.0$ litres

$\frac{4 \times 100}{4} = 100\%$
To calculate the ratio of FEV1 to FVC (FEV1%, FEV1/FVC or FER)

\[
\frac{\text{Actual FEV1}}{\text{Actual FVC}} \times 100
\]

e.g. FEV1 = 3.0 litres
FVC = 4.0 litres

\[
\frac{3}{4} \times 100 = 75\%
\]
Results classification

• Normal
• Obstructive
• Restrictive
• Combined
## Interpreting Spirometry

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Obstructive</th>
<th>Restrictive</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEV$_1$</strong></td>
<td>&gt;80%</td>
<td>&lt;80%</td>
<td>&lt;80%</td>
<td>&lt;80%</td>
</tr>
<tr>
<td><strong>FVC</strong></td>
<td>&gt;80%</td>
<td>&gt;80%</td>
<td>&lt;80%</td>
<td>&lt;80%</td>
</tr>
<tr>
<td><strong>FEV$_1$/FVC Ratio</strong></td>
<td>&gt;70%</td>
<td>&lt;70%</td>
<td>&gt;70%</td>
<td>&lt;70%</td>
</tr>
</tbody>
</table>
Flow volume trace

- **Peak expiratory flow**
- **FVC**

**Flow (l/second)**

**Volume (litres)**
Flow volume trace

- **Peak expiratory flow**
- **FVC**

**Volume (litres)**

**Flow (l/second)**
Obstructive defects

- COPD
- Asthma
- Bronchial carcinoma
- Bronchiectasis
# Assessment of Severity of Airflow Obstruction

<table>
<thead>
<tr>
<th></th>
<th>NICE 2004</th>
<th>GOLD 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Risk</strong></td>
<td><strong>FEV(_1) &gt; 80%</strong></td>
<td><strong>Mild</strong></td>
</tr>
<tr>
<td></td>
<td><strong>PREDICTED RATIO &lt; 70%</strong></td>
<td><strong>Moderate</strong></td>
</tr>
<tr>
<td><strong>Mild</strong></td>
<td><strong>FEV(_1) 50-80%</strong></td>
<td><strong>SEVERE</strong></td>
</tr>
<tr>
<td></td>
<td><strong>PREDICTED RATIO &lt; 70%</strong></td>
<td><strong>Very Severe</strong></td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td><strong>FEV(_1) 30-49%</strong></td>
<td><strong>SEVERE</strong></td>
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<tr>
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<td><strong>PREDICTED RATIO &lt; 70%</strong></td>
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<tr>
<td><strong>Severe</strong></td>
<td><strong>FEV(_1) &lt; 30%</strong></td>
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<tr>
<td></td>
<td><strong>PREDICTED RATIO &lt; 70%</strong></td>
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</tbody>
</table>

**Exempt from QOF if:**

*Not on medication/inhalers*
Obstructive
Obstructive flow volume trace
Restrictive defects
Pulmonary causes

- Fibrosing lung disease (CFA, UIP, EAA, rheumatiod)
- Parenchymal tumours
- Pneumoconiosis (coal workers, asbestosis, silicosis, siderosis)
- Byssinosis
- Pulmonary oedema
Restrictive defects
Non Pulmonary causes

• Musculoskeletal disorders
• Neuromuscular conditions
• Obesity
• Pregnancy
• Pneumonectomy/lobectomy
Restrictive
Restrictive flow volume trace
Combined defects

- Severe COPD
- Advanced bronchiectasis
- Cystic fibrosis
Combined flow volume trace
Example of printout

Normal Values: ECCS (adult):
Zapletal, Solymar, Cosswell (child)

Results at BTPS
Patient Name:  
ID:  
Date: 04/03/02  
Time: 17:05  
Sex: Female  
Age: 67  
Race: CAUCASIAN  
Height: 157 cm

### Spirometry Results

<table>
<thead>
<tr>
<th>TEST</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>FEV1</td>
<td>1.22</td>
<td>1.34</td>
<td>1.30</td>
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<tr>
<td>FVC</td>
<td>1.85</td>
<td>2.03</td>
<td>2.04</td>
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<td>PEF</td>
<td>250</td>
<td>278</td>
<td>251</td>
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<tr>
<td>VAR</td>
<td>-9</td>
<td>0</td>
<td>-1</td>
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#### Best Spirometry Result: Base = 2

--- Normal ---

<table>
<thead>
<tr>
<th>Base</th>
<th>%Pred</th>
<th>PostBD</th>
<th>%Pred</th>
<th>%Chg</th>
<th>Min</th>
<th>Pred</th>
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<td>FEV1</td>
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<td>1.10</td>
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<tr>
<td>FVC</td>
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<td>2.10</td>
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<td>PEF</td>
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<td>FEV1%</td>
<td>66</td>
<td>86</td>
<td>66</td>
<td>76</td>
<td>87</td>
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<tr>
<td>F25</td>
<td>0.24</td>
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<tr>
<td>MEF</td>
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<td>26</td>
<td>1.14</td>
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<td>3.94</td>
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<tr>
<td>R50</td>
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<td>MUV</td>
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<td>FET</td>
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</table>

Lung Age = 82 Years.

Interpretation: Normal Spirometry.
Reversibility testing???

NICE 2004 R12

In most patients suspected of having COPD, routine spirometric reversibility testing is not necessary as a part of the diagnostic process or to plan initial therapy with bronchodilators or corticosteroids. It may be misleading or unhelpful because

- Repeated FEV1 measurements can show spontaneous fluctuations
- Results on different occasions may be inconsistent and not reproducible
- Unless change in FEV1 is >400mls a single test may be misleading
- Definition of magnitude of significant change is purely arbitrary
- Response to long term therapy not predicted by acute reversibility testing

History is Key in distinguishing asthma from COPD
Patient preparation

To withhold or not to withhold medication?

If you are doing reversibility testing:
• No short acting bronchodilators for 4 hours
• No long acting bronchodilators for 12 hours
• No sustained release oral bronchodilators for 24 hours

For routine monitoring of COPD patients:
• Take all medication as usual
Bronchodilator reversibility

How?

- Beta$_2$ stimulant
- Anticholinergic bronchodilators
- Combination of beta$_2$ stimulant and anticholinergic
Bronchodilator reversibility

A positive result is:-

An increase in the FEV₁ that is greater than 400ml
Steroid reversibility

Why?
- To identify those patients who have asthma rather than COPD

When?
- During a period of clinical stability

How?
- 30mg oral prednisolone daily for two weeks.
History Suggests COPD and $\text{FEV}_1 < 80\%$ predicted

* FEV$_1$/FVC $< 70\%$

If in doubt

Bronchodilator Reversibility

400 mcg Salbutamol or equivalent Terbutaline

If FEV$_1$ improves $> 400$ mls

Asthma likely to be present

If no doubt

Diagnose COPD And follow COPD guidelines

If still In doubt

Steroid reversibility

Oral Prednisolone

30 mg daily for 2 weeks

If FEV$_1$ improves $< 400$ mls

If FEV$_1$ improves $> 400$ mls
Over to you