Spirometry practical guide and test interpretation
Use of spirometry pre-lung surgery

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Acknowledgements: Sarah Cameron, HEFT CF Dept
What is spirometry?

- ‘Method of assessing lung function by measuring the volume of air that the patient is able to expel from the lungs after a maximal inspiration’ (NICE 2004)

- Differentiates - obstructive/restrictive disorders

- Most effective way of determining severity (not signs/symptoms alone)

- MRC dyspnoea scale/QOL
Training

- ‘All healthcare professionals managing patients with COPD should be competent in the interpretation of the results of spirometry and all healthcare professionals performing spirometry should have undergone appropriate training and keep their skills up to date’ (NICE 2004)

- Association of Respiratory Technology and Physiology (ARTP)/BTS
  → Certificate of Competence
Lung Volumes
Types of spirometer

• Many different types £300 - £3000

• Hand held - FEV$_1$ & FVC readings

• Advanced - visual/printable traces

• Electronic - flow-volume curve

• Calculate %age predicted normal values

• Reports - defects, severity
Care of spirometers

- Ensure good care/maintenance of your spirometer → accurate & reproducible results

- Keep clean

- Accuracy checked regularly (manufacturers recommendations)

- Calibration (accuracy check) with large volume syringe

- Re-calibration by manufacturer

- NICE guideline emphasises importance of maintaining accuracy and recommends that spirometry services should be supported by quality control processes
Maintaining accuracy

- Patient technique - most common reason for inconsistent readings

To detect errors observe patient and trace:
- Inadequate/incomplete inhalation
- Lack of ‘blast’ effort during exhalation
- Additional breath taken during manoeuvre
- Poor seal with mouthpiece
- Slow start to forced exhalation
- Exhalation stops before complete expiration
- Some exhalation through the nose
- Coughing
Preparing the patient

- Comfortable/ seated
- Explain purpose/demonstrate technique
- Allow practice attempts
- Encourage full exhalation
- Limit total attempts to 8 or less/session
- 30 seconds rest between blows

Information:
- Age, gender, height
- Adjust normal values (Asian/Afro-Carribean)
- Note ??recent bronchodilator/exacerbation/pain
The manoeuvre

- Disposable one-way mouthpiece
- Instruct patient to ‘take the deepest breath possible, hold it, then place the filter into their mouth with a tight seal made by their lips.’

- Forced expiration - hard/fast as possible until no further air to expel (bleep)
  → severe COPD up to 15 seconds
- Avoid pursed-lips
- Nose clip/hold nose

- Repeat procedure - 3 readings (best 2 within 100ml/5%)
- Assess quality of each blow
The manoeuvre – in brief

- Full inspiration
- Inspiratory hold
- Avoid pursed-lips
- Forced expiration
  - hard/fast as possible
  - until no further air to expel
    - (severe COPD up to 15 seconds)

- Repeat procedure
  - 3 readings (best 2 within 100ml /5%)
Interpreting results

- Best of 3 consistent readings (FEV₁ & FVC)
- Borderline normal results - repeat in few months to confirm diagnosis (especially > 75 years)

Abnormality detected if any of following recorded:
- FEV₁ <80% predicted normal
- FVC <80% predicted normal
- FEV₁/FVC ratio <0.7

<table>
<thead>
<tr>
<th>Patient: 45 year old woman, height 5’3”</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁ Reading</td>
</tr>
<tr>
<td>FVC Reading</td>
</tr>
<tr>
<td>FEV₁/FVC</td>
</tr>
</tbody>
</table>

- Mild airflow obstruction → FEV₁ is between 50 and 80% of predicted normal & FEV₁/FVC is <0.7
Normal spirometry
- FEV₁
- FVC
- FEV₁/FVC
- VC
- FEV₁/VC
- FEV₁/FVC values based on age/gender/height
- Predicted values lower in non-caucasians
These values apply to Caucasians. Reduce values by 7% for Asians and by 13% for Afro-Caribbeans.

<table>
<thead>
<tr>
<th>Age</th>
<th>Height</th>
<th>Male</th>
<th>5'3&quot;</th>
<th>5'5&quot;</th>
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<tbody>
<tr>
<td></td>
<td>160cm</td>
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<td>3.81</td>
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<tr>
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</table>

For men over 70 years predicted values are less well established but can be calculated from the equations below (height in cm; age in years):

\[
FVC = (0.0576 \times \text{height}) - (0.026 \times \text{age}) - 4.34 \quad \text{(SD: ± 0.61 litres)}
\]

\[
FEV₁ = (0.043 \times \text{height}) - (0.029 \times \text{age}) - 2.49 \quad \text{(SD: ± 0.51 litres)}
\]
<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>Height</th>
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For women over 70 years predicted values are less well established but can be calculated from the equations below (height in cms; age in years):

\[
FVC = (0.0443 \times \text{height}) - (0.026 \times \text{age}) - 2.89 \quad (SD: \pm 0.43 \text{ litres})
\]

\[
FEV₁ = (0.0395 \times \text{height}) - (0.025 \times \text{age}) - 2.60 \quad (SD: \pm 0.38 \text{ litres})
\]
Consistent & inconsistent volume-time curves

Three consistent volume-time curves are required of which the best two curves are within 100ml or 5% of each other.

**Consistent:** Three acceptable and consistent traces.

**Inconsistent:** Although each trace is technically acceptable, they are inconsistent.
Identifying abnormalities

**Obstructive disorder**
- FEV$_1$ reduced (<80% predicted normal)
- FVC usually reduced but to lesser extent than FEV$_1$
- FEV$_1$/FVC ratio reduced (<0.7)

**Restrictive disorder**
- FEV$_1$ reduced (<80% predicted normal)
- FVC reduced (<80% predicted normal)
- FEV$_1$/FVC ratio normal (>0.7)
Obstruction

- Oedema
- Bronchospasm
- Floppy airways- reduced elastic recoil (emphysema/age)
- Tumour
- UAO
Restriction

- Lung
- Pleural
- Skeletal
- Soft tissue
- Abdominal
- neurological
Trouble shooting

- Slow start
- Cough
- Poor understanding/ submaximal effort- pain
- Fatigue/bronchospasm
- Early end of blow
- Glottic closure
- Leak- mouthpiece
Identifying abnormalities

**Coughing during exhalation**
- Abrupt stop in exhalation
- Short intake of air (start of cough)
- Irregular pattern of exhalation

**Slow start to forced exhalation**
- Marked increase in force of exhalation short time after start of manoeuvre (steep change in gradient on trace)
**Extra breath taken during manoeuvre**
- Extra breath shown by abrupt short plateau before total expiratory volume reached
- Following extra breath, total volume of air expelled > would have been with only original exhalation

**Early stoppage of manoeuvre**
- Normal start to manoeuvre
- Reaches plateau abruptly
Confirming COPD diagnosis via spirometry

- $\text{FEV}_1 < 80\%$ predicted  AND
- $\text{FEV}_1/\text{FVC} < 0.7 \ (70\%)$
- Asthma can show same abnormalities  $\rightarrow$ reversibility testing
- Spirometry - poor predictor of disability/QOL
Severity of airflow obstruction

- NICE COPD guideline definitions:
  - Mild $\rightarrow$ FEV$_1$ 50-80% predicted
  - Moderate $\rightarrow$ FEV$_1$ 30-49%
  - Severe $\rightarrow$ FEV$_1$ <30%

- Rx decisions based on severity
Consider COPD diagnosis in:

- Smokers/ex-smokers > 35yrs
- Exposure to respiratory irritants
- Chronic SOB, cough, sputum, recurrent chest infections, wheeze
COPD or asthma?

- Slow, progressive symptoms $\rightarrow$ COPD
- Symptoms pre-35 years $\rightarrow$ asthma
- Serial peak flow monitoring
- NICE - bronchodilator reversibility testing not routinely used where clinical features/spirometry indicate COPD
## COPD or asthma?

<table>
<thead>
<tr>
<th></th>
<th>COPD</th>
<th>Asthma</th>
</tr>
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<tbody>
<tr>
<td>Smoker or ex-smoker</td>
<td>Nearly all</td>
<td>Possibly</td>
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<tr>
<td>Symptoms under age 35 years</td>
<td>Rare</td>
<td>Often</td>
</tr>
<tr>
<td>Chronic productive cough</td>
<td>Common</td>
<td>Uncommon</td>
</tr>
<tr>
<td>Breathlessness</td>
<td>Persistent and progressive</td>
<td>Variable</td>
</tr>
<tr>
<td>Night time waking with breathlessness and/or wheeze</td>
<td>Uncommon</td>
<td>Common</td>
</tr>
<tr>
<td>Significant diurnal or day to day variability of symptoms</td>
<td>Uncommon</td>
<td>Common</td>
</tr>
</tbody>
</table>
## Reversibility testing

<table>
<thead>
<tr>
<th>Bronchodilator</th>
<th>Asthma</th>
<th>FEV&lt;sub&gt;1&lt;/sub&gt; before and after</th>
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</thead>
<tbody>
<tr>
<td>salbutamol</td>
<td>2.5–5mg (nebuliser) 200–400mcg (large volume spacer)</td>
<td>20 minutes</td>
</tr>
<tr>
<td>terbutaline</td>
<td>5–10mg (nebuliser) 500mcg (large volume spacer)</td>
<td>20 minutes</td>
</tr>
<tr>
<td>ipratropium bromide</td>
<td>500mcg (nebuliser) 160mcg (large volume spacer)</td>
<td>45 minutes</td>
</tr>
</tbody>
</table>

- Asthma indicated → large response to bronchodilator or 2/52 trial of 30mg Prednisilone daily (> 400ml)
  
  or

- Spirometry/clinical response 1/12 bronchodilator therapy

- RT - not ‘gold standard’ → interpret results with clinical Hx
Flow-volume measurement

- Basic spirometry $\rightarrow$ volume-time curve

- Flow-volume curve $\rightarrow$ expiratory flow rate plotted against the volume of air exhaled

- Overall shape of flow-volume curve $\rightarrow$ detects airflow obstruction at an early stage/provides additional information
Flow-volume loop
PEF, FEF
Identifying abnormalities

**Obstructive disorder**
- Peak expiratory flow (PEF) is reduced
- Decline in airflow to complete exhalation follows a distinctive concave curve

**Severe obstructive disorder**
- In severe airflow obstruction → characteristic ‘steeple pattern’ in expiratory flow trace

**Restrictive disorder**
- Pattern in expiratory trace normal in shape but absolute reduction in volume
Normal flow-volume curves

On exhalation, there is a rapid rise to the maximal expiratory flow followed by a steady, uniform decline until all the air is exhaled.

Inconsistent and consistent flow-volume curves

As with volume-time curves, three consistent flow-volume curves are required.

Inconsistent: Although each trace is technically acceptable, they are inconsistent.

Consistent: Three acceptable and consistent traces.
Spirometry in practice

Case Studies
MARION, COOK, AGED 55 YEARS

- Smoker since mid 20’s (30/day)
- Not as fit as she used to be. Jokes about “old age creeping on” and uses that excuse to avoid anything too strenuous
- Paces herself at work/delegating heavier jobs to younger colleague
- ↑ dyspnoea → difficulty keeping up with the family during walking
- no evidence of heart disease
- Only symptom → “smoker’s cough”
- On basis of history → provisional clinical diagnosis of COPD
**Examination**

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$FEV_1 = 1.39 \ (56% \text{ predicted})$</td>
<td>Reduced</td>
</tr>
<tr>
<td>$FVC = 2.53 \ (86% \text{ predicted})$</td>
<td>Normal</td>
</tr>
<tr>
<td>$FEV_1/FVC$ ratio = 0.55</td>
<td>Reduced</td>
</tr>
</tbody>
</table>

**Conclusion**
- Mild obstruction $\rightarrow$ firm diagnosis of COPD
- Marion unaware that smoking caused COPD
- Smoking cessation
- Bronchodilator inhaler ($\beta_2$-agonist or antimuscarinic) $\rightarrow$ improve exercise tolerance
RONALD, RETIRED BRICKLAYER, AGED 69 YEARS

- Bad chest for years

- Started smoking in army. Cigarettes cheap, socially acceptable & “good for you”

- After leaving army, smoked up to 40 cigarettes/day

- Retired 15 years ago on health grounds (SOBOE bricklaying)

- Productive cough and for some years/courses ABx for winter chest infections

- Unable to cope with working gardening/DIY

- Wife now complains → always “under her feet”

- Cyanosed
Examination

<table>
<thead>
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<tr>
<td>FEV₁ = 0.89 (28% predicted)</td>
<td>Reduced</td>
</tr>
<tr>
<td>FVC = 2.74 (67% predicted)</td>
<td>Reduced</td>
</tr>
<tr>
<td>FEV₁/FVC ratio = 0.32</td>
<td>Severe obstruction</td>
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### Conclusion
- Severe COPD (FEV₁ <30%)
- Bronchodilator therapy stepped-up
- Symptomatic benefit → combination of beta-agonists & antimuscarinics
- SPO₂ 89% on air
- ABG → chronic hypoxia (LTOT)
- Started on long acting bronchodilator (beta agonist or antimuscarinic)
- Due to FEV₁ <50% predicted/frequent exacerbations → started on inhaled steroid
JOHN, AN AREA SALES MANAGER, AGED 42 YEARS

- Always been “chesty”
- As a child considered “wheezy”/avoided PE
- Started smoking early 20’s (10 cigarettes/day since)
- Generally enjoyed good health/occasional URTI → coughing/wheeze
- Prescribed ABX to treat “bronchitis” → slow recovery (blamed smoking)
- Consulted his GP → another cold had “gone to his chest”
- Sleep disturbed by cough/wheeze
- Unclear on basis of history → asthma or COPD or both
Examination

- Bronchodilator response tested (4 puffs salbutamol)
- FEV$_1$ re-measured after 30 minutes

**Spirometry**

<table>
<thead>
<tr>
<th>Baseline</th>
<th>FEV$_1$ = 3.24 (76% predicted)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FVC = 4.82 (91% predicted)</td>
</tr>
<tr>
<td></td>
<td>FEV$_1$/FVC ratio = 0.67</td>
</tr>
<tr>
<td>Post-bronchodilator</td>
<td>FEV$_1$ = 4.17 (+ 930 ml and 29%)</td>
</tr>
</tbody>
</table>

**Interpretation**

- Slightly reduced
- Normal
- Slightly reduced
- Significant reversibility

**CONCLUSION**

- Mild degree of obstruction → highly responsive (significant reversibility) to bronchodilator
- Significant reversibility/clinical history are highly indicative → asthma
- Advised on long-term impact of smoking/risk of developing COPD
- Smoking cessation
EDDIE, A RETIRED PAINTER AND DECORATOR, AGED 65 YEARS

- Only recently complaining of cough/SOB
- Started smoking as young man
- Feels may have developed asthma
  - lives close to main road (affects of pollution)
  - 2 nephews recently diagnosed with asthma
- Otherwise fit and well/takes no medication
- Few fine crackles on auscultation
- Although asthma suspected → peak flow chart steady at 350 L/minute
Examination

**Spirometry**
- FEV$_1$ = 1.67 (57% predicted)
- FVC = 2.07 (55% predicted)
- FEV$_1$/FVC ratio = 0.81

**Interpretation**
- Reduced
- Reduced
- Normal

**Conclusion**
- Abnormal FEV$_1$ and FVC readings (both well below 80% of the predicted normal values)
- However the FEV$_1$/FVC ratio >70% → restrictive disease
- Fibrosing alveolitis diagnosed
- Condition unrelated to environmental air pollution
## Surgical risk levels

<table>
<thead>
<tr>
<th>Risks</th>
<th>± Low risk</th>
<th>++ Risky</th>
<th>+++ V HIGH risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppoFEV₁ %</td>
<td>&gt; 40%</td>
<td>30-40%</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>ppoDLCO %</td>
<td>&gt; 40%</td>
<td>30-40%</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>VO₂ (ml/kg/min)</td>
<td>&gt; 15ml/kg/min</td>
<td>10-15ml/kg/min</td>
<td>&lt; 10 ml/kg/min</td>
</tr>
<tr>
<td>Stair climb (flight)</td>
<td>&gt; 3</td>
<td>2-3</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>6-m walk (feet)</td>
<td>&gt; 2000</td>
<td>1-2000</td>
<td>&lt; 1000</td>
</tr>
</tbody>
</table>

Cahalin L, *Chest* 1995; **108**: 452-57  
Ninan M, *Ann Thorac Surg* 1997; **64**: 328-33
Guidelines on the radical management of patients with lung cancer

Eric Lim,1 David Baldwin,2 Michael Beckles,3 John Duffy,2 James Entwisle,4 Corinne Faivre-Finn,5 Keith Kerr,6 Alistair Macfie,7 Jim McGuigan,8 Simon Padley,9 Sanjay Popat,10 Nicholas Screaton,11 Michael Snee,12 David Waller,13 Chris Warburton,14 Thida Win,15 British Thoracic Society and the Society for Cardiothoracic Surgery in Great Britain and Ireland
Risk assessment for post-treatment dyspnoea

Spirometry and transfer factor

Low risk
ppoFEV1 ≥ 40% and ppo TLco ≥ 40%

Moderate to high risk¹
ppoFEV1 < 40% and / or ppo TLco < 40%

Functional assessment

Good

Moderate risk
Patients need to be informed of risk of moderate post-operative shortness of breath with surgery or radiotherapy

High risk²
Patients need to be informed of high risk of severe post-operative dyspnoea and / or long term oxygen therapy with surgery or radiotherapy

1. Consider split lung function testing for patients in this group if there is any suspicion of a ventilation perfusion mismatch (e.g., compression of a pulmonary artery or marked emphysema in the lobe with cancer) to allow more accurate estimation of post-operative values.

2. Patients in this subgroup are at high risk of ventilator dependency after surgery. It is important to ensure that criteria for LVRS have been considered as lung function can improve in appropriately selected patients.
Preoperative Respiratory Assessment

Respiratory Mechanics
- FEV1 (effort/absolute value)
- TLC
- RV
- FRC

Gas exchange
- DLCO
- ABG
- V/Q Scans

Cardiopulmonary reserve
- CPET
- Surrogate tests
  - Stairs climbing
  - Shuttle test
  - 6 min Walk
Predicted postoperative FEV1 (ppoFEV1)

$$\text{ppoFEV1} = \text{pre FEV1} \times \frac{(19 - \text{segments to be removed})}{19}$$

**obstructed segments**

$$\text{ppoFEV1} = \text{pre FEV1} \times \frac{(19 - a) - b}{19-a}$$

- $a = \text{obstructed segments}$
- $b = \text{unobstructed segments to be resected}$

<table>
<thead>
<tr>
<th>SEGMENTS</th>
<th>RIGHT</th>
<th>MIDDLE</th>
<th>LEFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPPPER</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIDDLE</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOWER</td>
<td>5</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>
V/Q Scans

- Useful in prediction of postoperative function.

- Postoperative FEV₁ = Preop FEV₁ x % radioactivity contributed by the non operated lung

- Better prediction is given by
  - PPO FEV₁ = Preoperative FEV₁ x % perfusion of the non operated side.