Spirometry Overview

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Faculty Disclosure

• I have no financial interests/arrangements that would be considered a conflict of interest.
Course Objectives

• To define what constitutes accurate and adequate spirometric assessment
• To discuss how spirometry performance and interpretation differ depending on age
• To review how pulmonary function assessment compares with other outcome measures in asthma
## Course Outline

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00 – 09:20</td>
<td>Thomas Casale</td>
<td>Spirometry overview</td>
</tr>
<tr>
<td>09:20 – 09:35</td>
<td>Omar Al Rawas</td>
<td>Factors affecting spirometric values</td>
</tr>
<tr>
<td>09:35 – 09:50</td>
<td>Steve Peters</td>
<td>How pulmonary function assessment compares with other outcome measures in asthma</td>
</tr>
<tr>
<td>09:50 – 10:00</td>
<td>All</td>
<td>Discussion</td>
</tr>
<tr>
<td>10:00 – 10:30</td>
<td>All</td>
<td>Hands on experience with spirometry</td>
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</tbody>
</table>
ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING

**Standardisation of spirometry**


**Interpretative strategies for lung function tests**

Indications For Spirometry

**Diagnostic**
- To evaluate symptoms, signs or abnormal laboratory tests
- To measure the effect of disease on pulmonary function
- To screen individuals at risk of having pulmonary disease
- To assess pre-operative risk
- To assess prognosis
- To assess health status before beginning strenuous physical activity programmes

**Monitoring**
- To assess therapeutic intervention
- To describe the course of diseases that affect lung function
- To monitor people exposed to injurious agents
- To monitor for adverse reactions to drugs with known pulmonary toxicity

**Disability/impairment evaluations**
- To assess patients as part of a rehabilitation programme
- To assess risks as part of an insurance evaluation
- To assess individuals for legal reasons

**Public health**
- Epidemiological surveys
- Derivation of reference equations
- Clinical research
## Equipment Quality Control

<table>
<thead>
<tr>
<th>Test</th>
<th>Minimum interval</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>Daily</td>
<td>Calibration check with a 3-L syringe</td>
</tr>
<tr>
<td>Leak</td>
<td>Daily</td>
<td>3 cmH(_2)O (0.3 kPa) constant pressure for 1 min</td>
</tr>
<tr>
<td>Volume linearity</td>
<td>Quarterly</td>
<td>1-L increments with a calibrating syringe measured over entire volume range</td>
</tr>
<tr>
<td>Flow linearity</td>
<td>Weekly</td>
<td>Test at least three different flow ranges</td>
</tr>
<tr>
<td>Time</td>
<td>Quarterly</td>
<td>Mechanical recorder check with stopwatch</td>
</tr>
<tr>
<td>Software</td>
<td>New versions</td>
<td>Log installation date and perform test using “known” subject</td>
</tr>
</tbody>
</table>
Closed Circuit Maneuver

Have subject assume the correct posture
Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece
Inhale completely and rapidly with a pause of <1 s at TLC
Exhale maximally until no more air can be expelled while maintaining an upright posture
Repeat instructions as necessary, coaching vigorously
Repeat for a minimum of three manoeuvres; no more than eight are usually required
Check test repeatability and perform more manoeuvres as necessary
Spirometry Values

- **FVC**: Forced vital capacity: the volume of air that can be maximally forcefully exhaled.
  - FEV$_6$ can be used as a measurement of FVC in adults
- **FEV$_1$**: Forced expiratory volume in one second (best measure of assessing airway obstruction)
- **FEV$_1$/FVC**: ratio expressed as a percentage (low values c/w obstructive lung disease)
- **FEF$_{25-75}$**: The average forced expiratory flow during the mid (25 - 75%) portion of the FVC
- **PEF**: (FEF$_{max}$) Peak expiratory flow (liters/second) rate during expiration (*peak flow meter measurements are in L/min*)
Within-maneuvre criteria

Individual spirometry are “acceptable” if
- They are free from artefacts [3]
  - 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
- They have good starts
  - Extrapolated volume <5% of FVC or 0.15 L, whichever is greater
- They 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

Between-maneuvre criteria

After three acceptable spirometries have been obtained, apply the following tests
- The two largest values of FVC must be within 0.150 L of each other
- The two largest values of FEV1 must be within 0.150 L of each other

If both of these criteria are met, the test session may be concluded
- If both of these criteria are not met, continue testing until
  - Both of the criteria are met with analysis of additional acceptable spirometries
  - or
  - A total of eight tests have been performed (optional) or
  - The patient/subject cannot or should not continue

Save, as a minimum, the three satisfactory manoeuvres
Application Of Reproducibility And Acceptability Criteria

- Perform FVC manoeuvre
- Met within-manoeuvre acceptability criteria?
  - Yes
  - No
  - Achieved three acceptable manoeuvres?
    - Yes
    - No
    - Met between manoeuvre repeatability criteria?
      - Yes
      - No
      - Determine largest FVC and largest FEV1
      - Select manoeuvre with largest sum of FVC + FEV1 to determine other indices
  - No
- Store and interpret
Percent Predicted Variables

- Gender: Males > Females
- Age: Its downhill after 20-25
- Height: The taller the Larger
- Ethnicity Matters:
  - Caucasians > Blacks and Indians > Chinese > Polynesians
Plateau of lung function between the ages of 20 and 30 then FEV1 falls approximately 20-30 mL per year.

- Smokers lose about 60 mL per year
Spirometry

Flow/volume curve

Spirogram: Vol / time
The normal volume time curve has a rapid upslope and approaches a plateau soon after exhalation. Volume (FEV1).

Normally the volume exhaled in one second is approximately 80% of the total volume, while the volume after 3 seconds is equal to the FVC.
Flow Volume Loops

Flow is plotted against volume to display a continuous loop from inspiration to expiration.

The overall shape of the flow volume loop is important in interpreting spirometric results.
Flow Volume loop

Effort Dependent

Effort Independent
# The Value Of FEV1 For Obstructive Lung Disease: Severity Classification

<table>
<thead>
<tr>
<th>0: At Risk</th>
<th>I: Mild</th>
<th>II: Moderate</th>
<th>III: Severe</th>
<th>IV: Very Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic symptoms</td>
<td>FEV₁/FVC &lt; 70%</td>
<td>FEV₁/FVC &lt; 70%</td>
<td>FEV₁/FVC &lt; 70%</td>
<td>FEV₁/FVC &lt; 70%</td>
</tr>
<tr>
<td>Exposure to risk factors</td>
<td>FEV₁ ≥ 80%</td>
<td>50% ≤ FEV₁ &lt; 80%</td>
<td>30% ≤ FEV₁ &lt; 50%</td>
<td>FEV₁ &lt; 30% or presence of chronic respiratory failure or right heart failure</td>
</tr>
<tr>
<td>Normal spirometry</td>
<td>With or without symptoms</td>
<td>With or without symptoms</td>
<td>With or without symptoms</td>
<td>With or without symptoms</td>
</tr>
</tbody>
</table>

## Classification of Asthma Severity

<table>
<thead>
<tr>
<th>Intermittent</th>
<th>Persistent</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal FEV₁ between exacerbations</td>
<td>FEV₁ &gt;80% predicted</td>
<td>FEV₁ &gt;60% but &lt;80% predicted</td>
<td>FEV₁ &lt;60% predicted</td>
<td></td>
</tr>
<tr>
<td>FEV₁/FVC normal</td>
<td>FEV₁/FVC normal</td>
<td>FEV₁/FVC reduced 5%</td>
<td>FEV₁/FVC reduced &gt;5%</td>
<td></td>
</tr>
</tbody>
</table>

NIH: Asthma
**TABLE 6** Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV1)

<table>
<thead>
<tr>
<th>Degree of severity</th>
<th>FEV1 % pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Moderate</td>
<td>60–69</td>
</tr>
<tr>
<td>Moderately severe</td>
<td>50–59</td>
</tr>
<tr>
<td>Severe</td>
<td>35–49</td>
</tr>
<tr>
<td>Very severe</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>
Forced Vital Capacity (FVC)

- Full inspiration to TLC
- Rapid, forceful maximum expiration to RV
- Effort dependent
- Differs from Slow Vital Capacity
  - Slow VC may be greater with obstruction
- Normal > 80%
- Generally = FEV6
Normal Patterns: Age Matters

Younger

Older
Figure 2. Mean (± SE) FEV₁/FVC Ratios Measured at 9, 11, 13, 15, 18, 21, and 26 Years in Male (Panel A) and Female (Panel B) Study Members, According to the Pattern of Wheezing.

FEV1/FVC

> 70 y/o healthy nonsmokers

### Normal FEV$_1$/FVC:

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 – 19 yr</td>
<td>85%</td>
</tr>
<tr>
<td>20 – 39 yr</td>
<td>80%</td>
</tr>
<tr>
<td>40 – 59 yr</td>
<td>75%</td>
</tr>
<tr>
<td>60 – 80 yr</td>
<td>70%</td>
</tr>
</tbody>
</table>

NIH asthma guidelines 2007
• Mean forced expiratory flow rate between 25% and 75% of the expired vital capacity
• Rate of air flow during the middle of the test
  – “midflows” MMEF (maximum midexpiratory flow)
• Reflects air flow in the peripheral or small airways
  – Less sensitive and specific
  – Largely effort independent
• Normal > 50%
Abnormalities are “not specific for small airway disease and, though suggestive, should not be used to diagnose small airway disease in individual patients.”

Am Rev Respir Dis 1991; 144:1202-1218
**PEF**

- Peak expiratory flow (L/sec)
  - Or $\text{FEF}_{\text{max}}$
- Measurement of FLOW not volume
- Effort dependent
- Measured in L/sec
- Handheld peak flow meter measured in L/min: PEFR
Spirometry should be interpreted using the flow volume and volume time curves as well as the absolute values for flows and volumes.
Flow Volume Loop Normal Patterns

Normal

Normal Variant “knee”
Obstructive pattern

**FIGURE 6.** Moderate airflow limitation in a subject with asthma.

**FIGURE 7.** Severe airflow limitation in a subject with chronic obstructive pulmonary disease.
Restrictive Disease

Shape of flow volume loop is relatively unaffected in restrictive disease:
- overall size of the curve will appear smaller when compared to normals.
- rapid upslope on the volume time curve, but such patients will reach a smaller vital capacity.

Restrictive lung disease cannot be diagnosed by spirometry alone.
### Obstructive vs Restrictive

<table>
<thead>
<tr>
<th></th>
<th>Obstructive</th>
<th>Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>$FEV_1$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$FEV_1/FVC$ %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$FEF_{25-75}$</td>
<td></td>
<td>normal</td>
</tr>
<tr>
<td>FRC</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>RV</td>
<td>normal</td>
<td></td>
</tr>
<tr>
<td>TLC</td>
<td>normal</td>
<td></td>
</tr>
</tbody>
</table>
Reversibility: ATS/ERS Task Force

- Four separate doses of 100 mcg should be used when given by MDI using a spacer. Tests should be repeated after a 15-min delay.

- An increase in FEV1 and/or FVC $\geq 12\%$ of control and $\geq 200$ mL constitutes “+” bronchodilator response.

- Increments of $<8\%$ (or $<150$ mL) are likely to be within measurement variability.
Unacceptable Patterns/ Maneuvers

Slow start

Did not exert maximal effort

May be lack of effort but may be normal if reproducible in young females

Called “rainbow curve”
Unacceptable Patterns / Maneuvers

Effort ended early
Falsely decreases FVC
Falsely increases FEF\textsubscript{25-75}

Stopped exhaling momentarily
"Sawtooth" pattern
Upper airway muscle weakness, Classic for OSA
Office spirometry

“When office spirometry shows severe abnormalities, or if questions arise regarding test accuracy or interpretation, further assessment should be performed in a specialized pulmonary function laboratory.”