STEP 1

Learning objectives

This module will provide you with an understanding of spirometry and the role it plays in aiding the diagnosis of lung diseases, particularly COPD. It is recommended that a spirometry should be performed during the initial assessment at pulmonary rehabilitation, however this may not be necessary if recent spirometry results are available.

By the end of this module you will be able to:
• understand what measurements are provided by spirometry
• describe how to perform a spirometry
• understand how to interpret spirometry results
• outline common spirometric features of obstructive and restrictive lung diseases
• describe how spirometry can indicate disease severity in COPD.

This module will provide introductory information on spirometry and its important role in the diagnosis of COPD. It will not include the practical aspects of spirometry or practice skills in conducting spirometry. Information will be provided on where spirometry training can be assessed.

STEP 2

Spirometry

Spirometry means, ‘the measuring of breath’. ‘Spiro’ = breath + ‘Metry’ = measure

Spirometry is the most reproducible, standardised and objective way of measuring airflow obstruction and FEV₁ is the variable most closely associated with prognosis¹. A spirometry test is a vital component in the diagnosis and monitoring of COPD.

A spirometer measures the amount of air that can be expired (blown out). Spirometry is essential in confirming a diagnosis of chronic lung disease² and therefore an important requirement for assessing patients for entry into a pulmonary rehabilitation program.

Spirometry is used in clinical practice to:
• aid the diagnosis of respiratory disorders
• assess the degree of disease or disability
• monitor disease progress
• monitor the effects of treatment - acute or chronic.

A spirometer can measure expired volumes and flows of air from the lungs³. Spirometry can give an indication of underlying lung damage by comparing results with predicted normal values. In order to compare results to predicted normal values, the patient’s date of birth, gender, height, weight and ethnicity are entered into the spirometer data base prior to each test. For identification purposes, the patient’s name is also entered. The patient is then instructed to inspire fully and then blow into the spirometer.
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Training is essential for operators to learn correct performance of spirometry and interpretation of results. Poorly performed spirometry may give erroneous results and increases the risk of misinterpreting the results. Spirometry training is available through:

- some tertiary institutions.

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Types of spirometers

Volume displacement spirometers measure the volume (amount) of air expired from the lungs.

Flow-Sensing Spirometers measure the flow of air expired from the lungs. Volume can be calculated from the flow.
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Spirometers measure:
- **FEV₁**: (Forced Expiratory Volume in one second) is the volume of air expired in the first second of a maximal expiration following a maximal inspiration. FEV₁ is used to measure how quickly air can be expelled from the lungs.
- **FVC**: (Forced Vital Capacity) is the maximum volume of air that can be expired forcefully after a maximal inspiration. Most adults with normal lung function are able to expire their vital capacity in less than 6 seconds.
- **FEV₁/FVC ratio**: The volume of expired air in the first second (FEV₁) compared with the total volume expired (FVC). Most healthy people with normal lung function can blow out approximately 80% of their air out within the first second i.e. the FEV₁/FVC ratio is 0.8. If the FEV₁/FVC ratio is less than 0.7 it means that there is airflow obstruction.
- **FEF 25-75%**: (Forced Expiratory Flow between 25-75% of vital capacity) is the mean forced expiratory flow in the middle portion of the FVC. This is sometimes called MEF 25-75% (maximum expiratory flow) 25-75%.
- **PEF** (peak expiratory flow). The PEF only provides limited information as it is mainly a measure of flow from the large airways and is effort dependent. Factors influencing PEF include the dimensions of the large airways, the force generated by the expiratory muscles (including patient effort) and conditions which limit chest expansion.

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**Types of graphs**

There are two types of graphs used to display results on a spirometer. These are:

**Volume-Time Graphs**

Volume-time graphs show the volume of air expired in the first second (FEV₁) and the total volume of air expired (FVC) after a maximal inspiration. The time (in seconds) is shown on the bottom line (x axis) and the volume is shown on the side line (y axis).

**Flow-volume loop**

This graph shows the change in flow during a maximal inspiration and a maximal expiration. The expiratory flows give the most information. The volume is shown on the x axis and the flow on the y axis. The expiratory flow-volume curve is shown above the x axis and the inspiratory flow-volume curve is shown below the x axis. The shape of the flow-volume loop is repeatable for any individual but varies considerably between individuals with different lung diseases. Only flow sensing devices will be able to display a flow.
volume curve.

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**Performing spirometry**

When performing spirometry there are three things you need to consider. These are:

**Preparation**

A health care provider must remember the following points when carrying out spirometry:

- explain the purpose of the test and demonstrate the procedure
- record and enter the patient’s age, height (bare foot), gender and ethnicity (non-Caucasians have lower predicted values)
- note what type (short acting / long acting) and when bronchodilator was last used
- have the patient sitting comfortably
- suggest the patient loosen any tight clothing
- ask the patient to empty the bladder beforehand if needed.

**Precautions**

Spirometry is extremely safe but should be avoided in the presence of:

- pneumothorax
- increased intracranial pressure
- increased risk of syncope
- chest pain
- abdominal, thoracic or eye surgery within the previous eight weeks
- haemoptysis
- nausea, diarrhoea or vomiting.

**Instructions**

It is important to be consistent when giving instructions to your patient. Each time you perform a spirometry test you should give the same type of instructions and a similar amount of encouragement. The components of instructing a patient to perform spirometry are:

- maximum inspiration - “Big breath in!”
- “Put the mouthpiece in your mouth with lips well around” or “make a good seal with your lips”
- blow or blast the air out as hard and fast and as long as possible - “Blow out!”
- provide vigorous encouragement - “Keep blowing, Keep blowing until you feel that your lungs are empty…”

Ensure lips are well sealed around the mouthpiece throughout the procedure and that the mouthpiece is between the teeth. Check that the tongue does not impede the flow of air. A nose clip may be used to prevent air escaping from the nose although this option is often left out as the amount of air that will ‘escape’ through the nose may not be considered significant enough to affect test outcomes.

Check the trace and repeat the procedure at least twice more until 3 acceptable readings are obtained. Poor technique can often be easily corrected by demonstrating the procedure to the patient yourself.
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**How many attempts should the patient have?**

The patient needs to have a minimum of three blows that meet acceptability criteria based on the test quality. Almost all currently used spirometers provide feedback to the operator about the quality of the test immediately after the blow. It is essential that the patient has:

- a rapid start to expiration with no hesitation
- no artifacts in the trace
- a minimum of 6 seconds of expiration (although many healthy people will blow all their air out in less than seconds). Patients with obstructive lung disease may take longer to get all the air out of their lungs so should be encouraged to ‘keep blowing’ until all the air is exhaled. Modern spirometers give feedback as to when the patient has fully exhaled.

The blows should be repeatable, as indicated by the best and the second best FVC being within 0.15L (150mls) of each other.

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**Acceptability**

Acceptable results should have a graph demonstrating a rapid start, be free from artefacts and have a satisfactory time of exhalation (minimum of 6 seconds).

**Good repeatability**

![Flow-volume curve](image1)

![Volume-time curve](image2)

**Poor repeatability**

![Flow-volume curve](image3)

![Volume-time curve](image4)
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Potential problems

Patient-related
The most common patient-related problems when performing the spirometry are:

- sub-maximal effort
- leaks between the lips and mouthpiece
- incomplete inspiration or expiration (prior to, or during the forced manoeuvre)
- hesitation at the start of the expiration
- cough (particularly within the first second of expiration)
- obstruction of the mouthpiece by the tongue
- vocalisation during the forced manoeuvre
- poor posture
- additional breath during procedure
- glottic closure. This should be suspected if flow ceases abruptly during the test rather than being a continuous smooth curve.

Recordings in which cough, particularly if this occurs within the first second, or hesitation at the start has occurred should be rejected. Vocalisation during the test will reduce flows and must be discouraged. Performing the manoeuvre with the neck extended often helps.

Instrument-related
These depend largely on the type of spirometer being used. On volume-displacement spirometers, look for leaks in the hose connections. On flow-sensing spirometers, look for rips and tears in the flowhead connector tube. On electronic spirometers, be particularly careful about calibration.
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Other considerations

Procedures that need to be implemented in the use of spirometers include:

1. **Maintaining the spirometer**
   Most spirometers are tough but use common sense and avoid treating the spirometer roughly such as dropping it. Suspect a problem if the numbers and print outs do not make sense, or fit in with the clinical picture or are variable, even if doing it correctly (this means you need to know how to do ‘good’ spirometry yourself).

2. **Infection control**
   The risk of passing infection to others and staff is very low but it is very important to maintain high levels of infection control at all times. Avoid using the spirometer if TB is suspected. At the very least disposable mouth pieces with a one way valve should be used when performing spirometry with a volume-time spirometer. If using a flow sensor spirometer, performing inspiratory flow measures using a mouthpiece with a micro bacterial filter will facilitate optimal infection prevention, allowing the performance of inspiratory and expiratory flow measurements. All mouthpieces are single use only. Wipe down the spirometer after each patient, using an approved cleaning agent as per the manufacturer instructions.

3. **Calibration**
   Spirometry standards recommend checking the calibration regularly (see manufacturer instructions as to the frequency required). A simple test of spirometer accuracy is to regularly perform spirometry on the same healthy person (often you or a colleague) as this provides a good “biological control”.

STEP 12

Interpretation

Once spirometry has been performed the results need to be interpreted and compared with predicted normal values. Predicted values are provided from equations within an auto spirometer or from charts and are based on research studies measuring spirometry in healthy populations. Spirometry can reflect two distinct patterns of lung disease i.e. obstructive lung disease and restrictive lung disease.

Patients with obstructive lung disease have difficulty expelling air. This is reflected in a low FEV$_1$ whilst maintaining near normal FVC. This results in a low FEV$_1$/FVC ratio.

Patients with restrictive lung disease do not have difficulty expelling air although volumes are reduced as the lungs are stiff and less compliant. This results in a normal or high FEV$_1$/FVC ratio:

- COPD is an example of an obstructive lung disease.
- Pulmonary fibrosis is an example of a restrictive lung disease.

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Obstructive lung disease

A patient with obstructive lung disease will have the following findings on spirometry:

- FEV$_1$/FVC ratio < 0.7 (or 70%)
- FEV$_1$ < 80% predicted
• FEF 25-75% < 60% predicted.

Spirometry is also used to establish the degree of disease severity in obstructive lung disease. Using the COPD-X Guidelines, COPD can be classified as mild, moderate or severe depending on the degree of reduction in FEV₁.

- MILD: FEV₁ = 60-80% predicted
- MODERATE: FEV₁ = 40-59% predicted
- SEVERE: FEV₁ < 40% predicted.

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The following graph shows a normal flow-volume curve compared to an obstructive pattern.

\[ \text{Normal} \]
\[ \text{Obstructive} \]

\[ \text{FEV₁/FVC} = 0.8 \ (80\%) \quad \text{FEV₁/FVC} < 0.7 \ (70\%) \]
\[ \text{FEV₁} < 80\% \text{ predicted} \]
The following graph shows a normal volume trace compared to an obstructive pattern.

**STEP 15**

**Reversibility**

To assess reversibility of airflow obstruction, perform spirometry **before** and 15 minutes **after** a bronchodilator. It is usual to administer 4 puffs (400mcg) of salbutamol given one puff at a time and each puff separated by 4 normal tidal breaths.

The salbutamol is administered to the patient via spacer (holding chamber). Percentage improvement is calculated as $100 \times \frac{(\text{post-bronchodilator} - \text{pre-bronchodilator})}{(\text{pre-bronchodilator FEV}_1)}$. (NB: This test for reversibility should be performed after bronchodilator has been withheld for at least 4 hours. However, the test of reversibility is usually done in a lung function laboratory and not as part of pulmonary rehabilitation).

An increase in FEV₁ that is both greater than 200ml and 12% above the pre-bronchodilator FEV₁ is considered to be a significant bronchodilator response. Greater than 200ml and 12% reversibility is indicative of asthma, a reversible obstructive lung disease, whereas less than this is considered to be a non-reversible obstructive lung disease.

**STEP 16**

**COPD vs Asthma**

Both COPD and asthma have features of airflow obstruction, however only asthma will show significant reversibility of airflow obstruction following bronchodilator. Performing a pre and post-bronchodilator spirometry helps to differentiate COPD from asthma but the test must be interpreted with consideration to clinical history. The diagnosis of asthma relies on an appropriate history and complete, or at least substantial, reversibility of airflow obstruction. The following table provides a summary of differences between asthma and COPD.
<table>
<thead>
<tr>
<th></th>
<th>COPD</th>
<th>Asthma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at onset of symptoms</td>
<td>Normally &gt; 40 years</td>
<td>Typically early in life but can occur at any stage</td>
</tr>
<tr>
<td>Symptoms</td>
<td>Progressively worse with time</td>
<td>Vary from day to day</td>
</tr>
<tr>
<td>Disease progression</td>
<td>Chronic, progressive disease leading to disability and death</td>
<td>Usually able to be well controlled, rarely fatal.</td>
</tr>
<tr>
<td>Lung Function</td>
<td>Airflow obstruction is not fully reversible</td>
<td>Airflow obstruction is reversible</td>
</tr>
<tr>
<td>Site of inflammatory response</td>
<td>Mainly affects the small airways and lung parenchyma, although inflammatory changes may also occur in the large airways&lt;sup&gt;5&lt;/sup&gt;.</td>
<td>Inflammation mainly located in the larger conducting airways, although small airways may also be involved in more severe disease&lt;sup&gt;5&lt;/sup&gt;.</td>
</tr>
</tbody>
</table>

Significant differences exist between asthma and COPD but these can be difficult to distinguish in the older adult. There is substantial overlap between asthma and COPD in people over the age of 55 and for those aged over 65 with airway obstruction, most will have both asthma and COPD.<sup>9</sup>

**STEP17**

**Restrictive lung disease**

A patient with airflow obstruction will have the following findings on spirometry:
- FEV₁/FVC ratio ≥ 0.8 (or 80%)
- FVC< 80% predicted

The following graph shows a normal volume trace compared to a restrictive pattern.
This graph shows a normal flow-volume loop compared to a restrictive pattern (similar in shape to normal but smaller).

STEP 18

Confirm diagnosis – case study
Video case study: spirometry test

STEP 19

Audio case study: post spirometry test

STEP 19

Module summary

This module will provide you with an understanding of spirometry and the role it plays in aiding the diagnosis of lung diseases, particularly COPD. You should now be able to:

• understand what measurements are provided by spirometry
• describe how to perform a spirometry
• understand how to interpret spirometry results
• outline common spirometric features of obstructive and restrictive lung diseases
• describe how spirometry can indicate disease severity in COPD.

Before continuing to the next module, you can test your learning of this module by completing a short quiz.
REFERENCES


8. Barnes PJ. Similarities and differences in inflammatory mechanisms of asthma and COPD. *Breathe*; 2011, Vol. 7; 229-238