Spirometry is a procedure that measures lung volumes and serves as a diagnostic tool to confirm or rule out a clinical diagnosis of conditions such as asthma and chronic obstructive pulmonary disease (COPD). It can also measure the effect of disease on lung function, screen individuals at risk of having respiratory diseases and aid further assessment.

Spirometry is a technique that community nurses should be familiar with and this article provides some background to the technique as well as demonstrating how it should be performed. The author also offers advice on how to interpret the results of spirometry and provides a patient case study.

The lungs are a unique internal organ with a soft, sponge-like texture. The interior of each lung contains extensive epithelial tissue, which means that they have a much larger total surface area than their exterior suggests. This large surface area is vital for the mechanics of gaseous exchange, the primary function of the lung.

Breathing is aided by the muscular diaphragm at the base of the thorax. Contraction of the diaphragm ‘pulls’ the bottom of the cavity that encloses the lung downward, thereby increasing the volume of the lung and decreasing pressure, allowing air to flow into the upper airways (mouth, nose, throat) unobstructed.

During normal breathing, exhalation is passive and muscle contraction is not necessary (the diaphragm simply relaxes). During breathing, the rib cage itself is also able to expand and contract to some degree through the use of the intercostal muscles, together with the action of other respiratory and accessory respiratory muscles. As a result, air is transported into or expelled out of the lungs.

These actions provide the lungs’ inspiratory and expiratory movement, while the ribs and spine also provide protection alongside the flexibility to allow breathing (Standring, 2008).

THE SPIROMETER

A spirometer is a piece of apparatus used to measure the volume of air inspired and expired by the lungs (Figure 1). The resulting spirogram will identify different types of ventilation patterns, including ‘normal’, ‘obstructive’, ‘restrictive’...
and ‘combined’. There are various types of spirometers and they use a number of different methods for measurement (e.g. pressure transducers; ultrasonic; water gauge).

Spirometry is one of the simplest ways of measuring the patient’s lung volume. It was traditionally performed in hospitals in large pulmonary function test (PFT) laboratories. However, more recently, technology has meant that the equipment has become smaller, portable and more suitable for use by community nurses and other primary care staff (British Thoracic Society [BTS], 2005).

Spirometry is a diagnostic tool that is used to confirm or rule out clinical diagnosis and should be a routine procedure in any primary care review of chronic obstructive pulmonary disease (COPD) or asthma. In fact, spirometry is now recommended as part of the management of patients with these diseases in many national and international guidelines (e.g. American Thoracic Society; European Respiratory Society; Association for Respiratory Technology and Physiology) (Levy et al, 2009; Primary Care Commissioning [PCC], 2013).

**WHEN TO CONDUCT A LUNG FUNCTION TEST**

Spirometry testing can be used to diagnose disease, monitor ongoing conditions and for public health/biomedical research. It should always be booked in and planned to allow time for clinicians to perform the test properly and for the patient to prepare correctly.

Spirometry testing can support a clinical medical history as part of an accurate diagnosis and can further measure the effect of disease on lung function, screen individuals at risk of having respiratory disease and assess the following:

- Preoperative risk
- Patients’ prognosis pre-lung transplant
- Lung function pre- and post-intervention, for instance before and after a trial of a new medication
- Differential diagnosis, eg. cardiac-related breathlessness.

As a monitoring tool, spirometry testing is also capable of:

- Assessing the progression of disease and its impact on lung function
- Monitoring occupational risk (e.g. exposure to industrial airborne particles)
- Checking for adverse reactions to drugs known to have pulmonary toxicity, e.g. chemotherapy.

When conducting biomedical research or clinical trials, spirometry is used as an outcome measure. It can also be used in epidemiological surveys and to compare health status.

**History**

Before performing any lung function test it is imperative that a respiratory history is taken. This is not only to verify potential diagnostic leads, but also to ascertain any infection risks, contraindications or immune deficiencies. Patients should be asked specifically about any recent haemoptysis (coughing-up blood), as well as tuberculosis and/or HIV status.

If there is a list of patients to be tested and the community nurse is aware in advance of any that are immunosuppressed they should be asked to attend first — this will reduce the risk of cross-infection. Furthermore, nurses should avoid performing spirometry if a patient has a history of haemoptysis of unknown origin — if they are unsure they can refer the patient to secondary care for further investigation.

**Infection risk**

Infection prevention is crucial in every community and acute NHS trust. Spirometry has very minor infection risks; however, as the mouthpiece and pneumotach (the light screen that is inserted into the machine’s airway) are used for multiple patients, infection control precautions should always be taken to minimise any cross-infection (Bacci et al, 2011).

Following local infection control guidelines is paramount to ensure infections are not spread. Furthermore, it is important to ensure that cleaning solutions do not damage the spirometer — check the manufacturer’s guidelines before cleaning. Community nurses should make sure they have the correct disposable mouthpieces and that these comply with local infection control standards.

The use of low-resistance barrier filters and disposable one-way valve mouthpieces significantly reduces the risk of bacterial cross-infection. Inspiration through flow-based spirometers fitted with disposable cardboard mouthpieces is safe when combined with spirometer disinfection/sterilisation between subjects (Bacci et al, 2011).

This helps to protect the equipment from exhaled secretions, but it is vital that a new filter is used for each patient.

**PREPARATION**

**Equipment**

Community nurses should regularly check any equipment such as spirometers used in their clinical setting. It is important that any equipment is properly maintained and is able to provide reliable and reproducible readings, which can be relied upon clinically. Therefore, the following questions should be asked:

- How old is the spirometer?
- When was it last serviced?
- Is it calibrated annually?
- Is the calibration checked daily?

Calibration is performed by the manufacturer and it is important that the equipment is sent away to be checked annually.

On a day-to-day basis, nurses need to perform and record calibration checks using a three litre syringe to ‘blow’ air into the spirometer mouth piece and over the pneumotach. This is to ensure the spirometer is still functioning within reliable parameters — to be within acceptable limits it must give a reading +/- 3% of three litres (if a three litre syringe is used).
Calibration should be verified before every clinic/session or after every 10 patients (whichever comes first). A calibration log should be kept, dated and signed. The age of the patient can affect performance, so nurses must ensure they keep and maintain accurate records (Falaschetti et al, 2004; PCC, 2013).

Preparing the patient: predicted values
Predicted values are necessary to ‘benchmark’ a patient’s results against the rest of the population. Predicted values were derived from previous studies that collected a large amount of lung function data for specific populations, e.g. coal and steel workers or cross-sections of the US public (Quanjer et al, 1993; Hankinson et al, 1999; Fallashetti et al, 2004).

The population that the particular clinic or trust serves should influence the nurse’s selection of predicted values. The values are based on a patient’s age, gender, and height and all of these must be collected accurately to ensure the correct predicted values are derived. Most computerised spirometers will calculate the predicted value equations, but nurses should still ensure the correct population values are selected.

Positioning
It is important to explain the purpose of the test to patients as well as describing clearly what they will be asked to do. It is helpful for nurses to demonstrate the procedure and emphasise the importance of taking a full breath before expiring as fast and hard as possible for a FVC (forced volume capacity — the amount of air that can be forcibly exhaled from the lungs following the deepest breath possible) and slow and steady for a VC (vital capacity) (see Table 1).

The patient should be comfortable and preferably have recently emptied their bladder, as coughing during the procedure could cause urinary incontinence. Ideally, they should be seated for the procedure as there is a small risk of syncope (loss of consciousness caused by falling blood pressure), which is greater if standing. Therefore, use a chair, with arms and no wheels.

Performance
Initially, community nurses should ensure the test is properly explained...
Table 1: What is being measured and why?

<table>
<thead>
<tr>
<th>Lung function values</th>
<th>Meaning</th>
<th>Reason</th>
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<tbody>
<tr>
<td>FEV1</td>
<td>Forced expiratory volume in one second</td>
<td>Measures how quickly a person can exhale</td>
</tr>
<tr>
<td>FVC</td>
<td>Forced vital capacity</td>
<td>Measures maximum volume exhaled from full inspiration with maximum effort</td>
</tr>
<tr>
<td>PEF</td>
<td>Peak expiratory flow rate</td>
<td>The maximum speed of the exhaled air flow</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>The FEV1/FVC ratio is the FEV1 expressed as a percentage of the FVC (or the VC if that is greater), i.e. the proportion of the vital capacity exhaled in the first second</td>
<td>This distinguishes between reduced FEV1 due to restricted lung volume and that due to obstruction. A figure under 70% indicates airflow obstruction</td>
</tr>
<tr>
<td>FEV1/VC</td>
<td>The slow vital capacity ratio — FEV1 from a forced manoeuvre as a proportion of total exhaled volume measured from a slow (non-forced) blow (VC)</td>
<td>A figure under 70% indicates airflow obstruction. It can be a higher figure allowing for 'air trapping' in some patients</td>
</tr>
</tbody>
</table>

Nurses should also take into consideration disorders that may influence the test performance or make the test uncomfortable for patients, including:

- Haemoptysis of unknown origin
- Pneumothorax (collapsed lung)
- Unstable cardiovascular status, e.g. myocardial infarction in the last month or pulmonary embolism
- Thoracic, abdominal or cerebral aneurysm: there is a danger of rupture during testing due to increased thoracic pressure
- Recent eye surgery: forced spirometry will increase intraocular pressure
- Nausea or vomiting
- Nurses should also note that recent exacerbations of respiratory illnesses as the patient’s lung function may decrease as a result.

Once the nurse is comfortable by the FVC procedure, which can also cause changes in blood pressure.

Furthermore, it is important to note when the patient’s last dose of inhaled medication was taken, particularly beta-2 agonists (e.g. salbutamol), as this will significantly influence the result of the lung function tests in respiratory conditions such as asthma. Asthma is considered a reversible airways disease, as patients’ lung function (FEV1 — forced expiratory volume in one second) improves in response to inhaled salbutamol (National Institute for Health and Care Excellence [NICE], 2016).

Any community nurse needs an understanding of why spirometry is being performed so that they can ascertain if the patient should refrain from taking any inhaled therapies before testing. For example, if the patient is having a diagnostic test, they may need to suspend taking medication such as salbutamol (Miller et al, 2005); whereas if they are undergoing a monitoring test, medication may not need to be withheld — in this way, a true picture of functional capacity of the patient can be developed (NICE, 2010).

Once the nurse is comfortable that it is safe for the patient to undergo a spirometry test, it is important to ensure that they are comfortable and that the procedure has the best chance of success. This means advising patients to avoid the following (Table 2):
- Smoking 24 hours before testing (PCC, 2013)
- Consuming alcohol four hours before testing
- Performing vigorous exercise 30 minutes before testing
- Wearing clothing that substantially restricts full chest and abdominal expansion
- Eating a large meal two hours before testing (Miller, 2005).

Once the test begins, the patient should be asked to perform three slow, relaxed blows into the spirometer. These relaxed blows are performed initially to enable the patient to fully expel all of their breath without any possible bronchoconstriction that may arise during forced manoeuvres. It is imperative that the patient is provided with a nose clip at this point to ensure that they are not tempted to breathe in through their nose before exhaling.

The nurse should then attach...
a clean, disposable, one-way mouthpiece to the spirometer and instruct the patient to breathe in (away from the mouthpiece) until the lungs feel ‘full’. The patient should be asked to hold their breath for long enough to seal their lips tightly around the mouthpiece, before being requested to ‘blast’ the air out as forcibly and as fast as possible until there is none left to expel. This will help the nurse to assess the FVC and the forced expiratory volume of air that can be expelled in the first second after a maximum inhalation (FEV1) (see Table 1).

Next, the patient should be instructed to breathe in deeply and completely fill their lungs before expiring all their breath at a slow and steady pace, until the lungs are completely empty. They repeat this three times, ensuring that they have time to recuperate between these lengthy breaths (the slow or relaxed VC manoeuvre).

The nurse should verbally encourage the patient to continue blowing into the spirometer during this phase — this is referred to as coaching. The nurse should also observe the patient to make sure they have achieved a good ‘seal’ with their lips around the mouthpiece. It is also important to check that an adequate trace has been achieved (the trace is the printout including the diagram of the flow volume loop — see below).

The procedure should be repeated (up to eight times) until three acceptable and repeatable blows are obtained. This is a blow that can be easily replicated within 5% or 150mls of the others — 150ml or 5% are the repeatable parameters, i.e. the acceptable difference between blows to ensure repeatability.

These blows should also be free from so-called ‘artefacts’ such as cough; slow start; abrupt end; failing to expire all of the breath. These artefacts indicate that the test may not be of high quality. If possible (i.e. if the patient is not too tired), the blow should be repeated (see Figure 2).

The nurse needs to adhere to specific clinical quality guidelines (Global Initiative for Lung Disease [GOLD], 2015), to ensure that the spirometry test is of sufficient quality to make a diagnosis. The guidelines recommend that at least three blows should be performed and that these should all be repeatable (as above). The ‘best’ blow, or combination of the blow with the best FEV1 and FVC should be chosen (see Table 1).

PCC (2013) guidelines explain that the best values are:
- Three technically acceptable results selected from up to eight possible efforts
- Repeatability criteria are met when there is no more than 100mls ideally (and certainly no more than 150mls in the occasional highly variable patient) between each blow
- Highest FEV1, VC and FVC from three efforts meeting repeatability criteria or within 5% of each other — whichever

Figure 2.
Examples of ‘artefacts’, or poor blows.

Figure 3.
Reading the curve — flow volume loops themselves provide indications towards diagnosis
is smaller (below one litre) or higher (above one litre)

The highest FEV1, VC or FVC can come from any one of the three efforts meeting repeatability criteria (they do not have to come from the same blow).

INTERPRETATION

Understanding the flow volume curve and the spirometry results is vital to ensure accurate diagnosis and treatment options (Table 1). Firstly, the name, age and predicted values should be checked and the nurse should ensure that they have the correct documentation. Secondly, the repeatability of the blows should be checked, as well as the correct calculations for the correct blow and the best blow.

Nurses should look at the curve, not just the numbers — Figure 3 shows a range of flow volume loops. If the expiration is concave and elongated, this can represent an element of obstruction. If, however, the curve is shorter and smaller, this can be representative of restrictive disease patterns. However, to confirm this, the nurse must next look carefully at the figures.

Figure 4 shows a section from a spirometry printout, with the patient having a predicted FEV1 for their age and height of 3.17 litres. The FEV1 on the printout, however, reads 0.57 litres and 18% of predicted value; while the FVC reads 1.30 and 32% of predicted value, indicating very severe obstruction (FEV1: 18%) with perhaps an element of restrictive disease (decreased FVC: 32%). This, combined with a full medical and drug history, including risk factors and current symptoms, may indicate COPD with perhaps concurrent restrictive disease. Therefore, a chest X-ray and referral to a secondary care respiratory consultant would be recommended for this patient, to ensure correct medical management of their disease.

GOLD (2015) guidelines are used by the author to classify airflow obstruction (Table 3).

CONCLUSION

Community spirometry is now possible with mobile equipment and is a vital tool for community respiratory services. This paper highlights some of the key aspects of performing spirometry, however, which helped him to understand the process. Furthermore, together they agreed to prolong the waiting time between blows, to ensure that he was fully rested; in this way fewer blows/ attempts were required to ensure a reliable reading.

The patient commented: ‘I know I have to get the blows correct so that the nurses can accurately assess my condition. Once I understood the process and they gave me the time, I found it easier. It helps that I know them well.’

Therefore, it can be seen that allowing time for patient preparation, explanation and practice attempts, can improve the quality of community nurses’ lung function testing.
spirometry to inform the diagnosis and guide the care they provide for primary care patients.

References


Table 3: Gold international guidelines [2015]

<table>
<thead>
<tr>
<th>Standard</th>
<th>FEV1 / FVC below .70</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold stage 1</td>
<td>Mild</td>
<td>FEV1 same as or above 80% of predicted</td>
</tr>
<tr>
<td>Gold stage 2</td>
<td>Moderate</td>
<td>FEV1 same as or above 50% and below 80% of predicted</td>
</tr>
<tr>
<td>Gold stage 3</td>
<td>Severe</td>
<td>FEV1 same as or above 30% and below 50% of predicted</td>
</tr>
<tr>
<td>Gold stage 4</td>
<td>Very severe</td>
<td>FEV1 below 30% of predicted</td>
</tr>
</tbody>
</table>


WHAT’S YOUR NEXT STEP?

To use the knowledge that you have gained from this article to inform your continuing professional development (CPD), you should take the following steps before logging onto the website (www.jcn.co.uk/learning-zone/) to take the learning zone test:

Reflect
Do you understand what the spirometer is designed to measure?
What are the main conditions associated with spirometry?

Evaluate
Do you appreciate how the patient can be negatively affected COPD?

Act
Read the article when you have a spare few minutes in the day. Make some notes on what you have learned, then visit the online test (www.jcn.co.uk/learning-zone/) to complete this subject.

The whole test, which involves reading this article and answering the online questions, should take you 90 minutes to complete.

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Five-minute test

Answer the following questions about this article, either to test the new knowledge you have gained or to form part of your ongoing practice development portfolio.

1 – What is the main measure that spirometry is used for?
2 – What are the main conditions associated with spirometry?
3 – Why is it important to test a patient’s lung function?
4 – What do the terms FEV1 and FVC stand for?
5 – Do you understand the significance of the flow volume curve?
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