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Spirometry

What is spirometry?

Spirometry is a test of lung function, used in the diagnosis of conditions such as chronic obstructive pulmonary disease (COPD). Spirometry is a safe and practical procedure; the majority of patients are able to provide acceptable and repeatable results. This allows potentially wide application of testing to improve recognition and diagnosis of COPD , such as for case finding in primary care.

However, COPD remains substantially under-diagnosed in primary care and papers over the period of a decade have cited the underuse of spirometry as a reason for this. With the lack of availability of spirometry during the COVID-19 pandemic, this situation is likely to have worsened as it may take some time for the backlog to be cleared.[1] [2]

Spirometry may also be useful for asthma, cystic fibrosis, congenital or acquired airway malformations and many other respiratory diseases in children.[3]

A spirometer is a device for measuring timed expired and inspired volumes; hence, it indicates how quickly and effectively the lungs can be emptied and filled.

- Spirometry should be used to diagnose airflow obstruction in patients with respiratory symptoms.
- Spirometry can also be used to monitor disease progression and also rehabilitation and treatment gains.
- There is strong epidemiological evidence to indicate that reduced expiratory volume in one second (FEV1) is a marker of cardiovascular mortality, independent of age, gender and smoking history.[4]

- Spirometry is the gold standard method for the diagnosis, assessment and monitoring of COPD and can also be used to demonstrate obstruction of airways in the diagnosis of asthma.[5] [6]

Poorly performed spirometry produces misleading results and there have been some concerns regarding the validity of some primary care spirometry. However, studies incorporating training have found no differences between test results produced in primary care and in pulmonary function laboratories.[7] Anyone performing spirometry should be fully trained and should undertake regular updates. Quality audits should also be routine. Spirometry may be performed at a GP practice, or at a locally commissioned hub, depending on local pathways and funding arrangements.

Types of spirometry devices

Many remember the large volume-displacement devices with bellows or water-sealed bell beloved of physiology laboratories but the spirometers most commonly used in primary care are now electronic, flow-sensing devices:

1. Small, hand-held devices that provide digital readings. These are the cheapest options and will fit into a medical bag but do not provide a graphical display (spirogram) and therefore it may be difficult to judge when an expiration is complete. They also need to be used in combination with predicted charts and a calculator to interpret results.
2. Portable meters with integrated printers. Typically more expensive than (1.) but will provide calculations, spirograms to monitor the blow and a printout including a flow volume loop.
3. Systems designed to work with a computer that will display a graph, make calculations of predicted values and reversibility and provide a printout for records. They also enable tests to be emailed for a second opinion and for electronic storage.

Whatever equipment is used, devices should be regularly calibrated, maintained, cleaned and disinfected according to the manufacturer's instructions. Disposable 'one-way' valved mouthpieces reduce the risk of cross infection (but prevent inspiratory flow-volume loops). Good practice should be to keep a calibration and maintenance log and list of patients tested with the spirometer (eg, to enable contact tracing in case of unwitting testing of a patient with tuberculosis).

Instructions for spirometry

- Prior to testing, the patient's condition should be stable (ideally six weeks since the last exacerbation).
- Standing is not mandatory but may provide better results. Sitting is safer for the elderly and infirm; if sitting, then the patient should sit straight up, with their head slightly extended.
- Breathe in maximally.
- Hold the mouthpiece between the teeth and then apply the lips for an airtight seal.
- Breathe out as hard and as fast as possible. The patient should aim for maximal flow at the moment expiration starts. With handheld devices, watch the vane rotating and make sure it does not start rotating while the spirometer is brought to the lips, thus avoiding artefacts.
- Keep breathing out until the lungs are 'empty'.
- Some get the users to practise just emptying their lungs, ie to do a slow vital capacity (SVC - the amount of air that can be breathed out during the largest possible breath when breathing gently) before getting them to repeat the same as quickly as possible. This allows comparison of the SVC with the forced vital capacity (FVC - the maximum amount of air a person can expel from the lungs after a maximum inspiration) and allows the user to discard poor attempts where the FVC is below the expiratory volume.
- Limit the total number of attempts (practice and recording) to eight.

Three satisfactory blows should be performed and best values taken for interpretation. Criteria for satisfactory blows are:

- The blow should continue until a volume plateau is reached - this may take more than 12 seconds in severe COPD.
- FVC and FEV1 readings should be within 5% or 100 ml.
- The expiratory volume-time graph should be smooth and free from irregularities.

Reversibility testing

Important information
Reversibility - an increase of >400 ml from baseline in FEV1 is suggestive of asthma. Smaller increases are less discriminatory.[5]

- Perform baseline spirometry first.
- Bronchodilator reversibility testing: before undertaking bronchodilator testing, the patient should stop short-acting $beta_2$ agonists for 6 hours, long-acting bronchodilators for 12 hours and theophyllines for 24 hours. Administer bronchodilator (at least 400 micrograms salbutamol) and repeat spirometry after 15 minutes.
- Steroid reversibility testing: a steroid trial (30 mg prednisolone daily for 2 weeks or 200 micrograms beclometasone or equivalent inhaled corticosteroid for 6-8 weeks) is undertaken.

Spirometry measurements

Measurement	Definition	Interpretation
Vital capacity (VC)	**Slow vital capacity (SVC)** - maximal amount of air exhaled steadily from full inspiration to maximal expiration. Not time-dependent. **Forced vital capacity (FVC)** - volume of lungs from full inspiration to forced maximal expiration. Expressed as a percentage of the predicted normal for a person.	SVC should be >80% predicted, reduced in restrictive disease. FVC is reduced in restrictive disease and also in obstructive disease if air-trapping occurs.
Forced expiratory volume in one second (FEV1)	Volume of air expelled in the first second of a forced expiration.	Reduced in both obstructive and restrictive disease.
Forced expiratory ratio (FER) %	(FEV1/FVC) x 100 Percentage of FVC expelled in the first second of a forced expiration.	Remains normal (or even elevated) in restrictive disease, reduced in obstructive disease.
Forced expiratory flow between 25-75% (FEF 25-75%) Also known as maximum mid-expiratory flow (MMEF)	Average expiratory flow rate in the middle part of a forced expiration. It is a sensitive indicator of what is happening in the middle and lower airways but is not as reproducible as FEV1.	Normal in restrictive disease.

Interpreting spirometry readings

NB: always repeat a series of readings on another occasion before basing a diagnosis on spirometry.

For a full assessment you need to:

- Consider the spirometry derived values: FEV1, FVC.
- Calculate the FEV1/FVC ratio.
- Compare these with the individual's predicted values (based on age, sex, race and height).

FEV1

FEV1 is strongly recommended as the measurement of choice in COPD as:

- It is reproducible and objective with well-defined normal ranges.
- It can be measured quickly and easily at all stages of disease. In very advanced COPD, forced expiration may result in closing of airways and trapping of air, so SVC may be a better measure of lung function.
- Variation on different occasions on the same patient is low (<170 ml).
- FEV1 is a good predictor of future morbidity and mortality, better than FEV1/FVC.
- Serial measurements provide evidence of disease progression.
- Peak flow measurements do not distinguish between obstruction and restriction of airflow and may seriously underestimate the degree of airway obstruction in COPD.
- In mild asthma, FEV1 is likely to show up the lesser degrees of airflow obstruction occurring later in the expiratory effort.

FVC

- There is likely to be a reduction in FVC in patients with moderate-to-severe COPD, which is caused by the alveolar damage and coalescence, together with loss of elasticity of the lung tissue.
- Patients with chronic asthma may have a reduction in FVC.

FEV1/FVC ratio

- A ratio of <70% implies obstructive disease.

- In older patients, the FEV1/FVC may fall to <70% in the absence of airway obstruction, so use tables to compare to predicted values; however, in everyone, if the value is >70%, obstruction is effectively excluded.
- The hallmark of an obstructive defect is slowing of expiratory flow, so that a low proportion of the FVC is expired in the first second and the FEV1/FVC ratio is reduced.
- If the patient has a restrictive ventilatory defect, the FEV1 and FVC are both reduced but in proportion, so the FEV1/FVC ratio remains normal (greater than 75%).
- Restrictive ventilatory defects can be due to various intrapulmonary diseases (eg, pulmonary fibrosis, pulmonary oedema, collapse or consolidation of the lung) but also importantly with extrapulmonary conditions (eg, large pleural effusion, rib cage deformity (scoliosis), after lung surgery and with weakness of the respiratory muscles). Clearly, the measurements need to be interpreted in the clinical context and, if a restrictive abnormality is discovered, CXR is usually essential for interpretation.

Restrictive and obstructive patterns

Abnormal spirometry is divided into restrictive and obstructive ventilatory patterns:

- **Restrictive ventilatory pattern**: due to conditions where lung volume is reduced - eg, fibrosing alveolitis, scoliosis. The FVC and FEV1 are reduced proportionately:
    - FVC reduced <80%.
    - FEV1 reduced.
    - FEV1/FVC normal.

- **Obstructive ventilatory pattern**: due to conditions in which airways are obstructed due to diffuse airways narrowing of any cause - eg, asthma, COPD, extensive bronchiectasis, cystic fibrosis, lung tumours. The FVC and FEV1 are reduced disproportionately:

    - FVC normal or reduced.
    - FEV1 reduced <80%.
    - FEV1/FVC reduced <70%.

Flow volume loops

Flow volume loops show flow rate as the lung empties - the shape of the loop depends on the mechanical properties of the lung and different diagnoses provide different shaped loops:

- Normal - on exhalation there is a rapid rise to the maximal expiratory flow, followed by a steady uniform decline until exhalation is complete.
- Asthma - typically the curve is a smooth concave shape as airway obstruction is relatively constant throughout expiration.
- COPD - typically the curve is angled or 'kinked' as COPD lungs collapse with forced expiration.
- Restrictive disease - the curve is typically a normal height but with a very steep gradient as the lung volume is diminished.

See 'Further Reading and References' for diagrammatic illustration of flow volume loops.

Uses of spirometry in primary care

All patients with suspected COPD should ideally have spirometry performed to aid initial diagnosis.

A substantial proportion of patients clinically identified as having COPD in general practice do not have the condition according to spirometry criteria, with inaccurate diagnosis more common in patients with comorbidities.[8]

COPD[9]

See the separate Chronic Obstructive Pulmonary Disease and Diagnosing COPD articles.

- Spirometry is fundamental to making a diagnosis of COPD and a confident diagnosis of COPD can only be made with spirometry. However, there is no single diagnostic test for COPD. Making a diagnosis relies on clinical judgement based on a combination of history, physical examination and confirmation of the presence of airflow obstruction using spirometry.
- Spirometry is the only accurate method of measuring the airflow obstruction in patients with COPD. Peak expiratory flow rate (PEFR) measurement may significantly underestimate the severity of the airflow limitation.
- A diagnosis of airflow obstruction can be made if the FEV1/FVC <0.7 (ie 70%) and FEV1 <80% predicted.
- National Institute for Health and Care Excellence (NICE) classification of the severity of COPD:
    - Stage 1 - mild: 80% or above (symptoms should be present to diagnose COPD in people with mild airflow obstruction).
    - Stage 2 - moderate: 50-79%.
    - Stage 3 - severe: 30-49%.
    - Stage 4 - very severe: below 30% (or FEV1 less than 50% but with respiratory failure).
- The presence of airflow obstruction should be confirmed by performing post-bronchodilator spirometry.
- Changes in the flow volume loop may give additional information about mild airflow obstruction.
- Measurement of the SVC may allow the assessment of airflow obstruction in patients who are unable to perform a forced manoeuvre to full exhalation.
- Spirometry can be used to assess the severity of airflow limitation and can help predict the prognosis.

- All patients with COPD should have their FEV1 monitored annually to assess progression of their disease, as the level of FEV1 is related to complications such as development of respiratory failure or pulmonary hypertension. Serial measurements over a few years allow assessment of rate of decline of FEV1, an indicator of mortality risk in COPD.
- Spirometry is a poor predictor of disability and quality of life in COPD. Spirometry alone cannot separate asthma from COPD.
- Alternative diagnoses or investigations should be considered in:
    - Older people without typical symptoms of COPD where the FEV1/FVC ratio is <0.7.
    - Younger people with symptoms of COPD where the FEV1/FVC ratio is 0.7 or higher.
- European Respiratory Society (ERS) 1993 reference values are currently used but these may lead to under- diagnosis in older people and are not applicable in black and Asian populations because definitive spirometry reference values are not currently available for all ethnic populations.

Asthma[5]

- Spirometry is now preferred over PEFR measurement for confirmation of obstruction of airways in the diagnosis of asthma in adults and children with an intermediate probability of asthma able to undertake it (children under 5 years are unsuitable for this form of testing and there is great variation in the 5-12 year range). It is felt to offer clearer identification of airway obstruction and to be less effort-dependent.
- Spirometry may be normal in individuals currently asymptomatic and does not exclude asthma; it should be repeated, ideally when symptomatic. However, a normal spirogram when symptomatic *does* make asthma an unlikely diagnosis.

- In those with evidence of airway obstruction and an intermediate probability of asthma, arrange reversibility testing and/or a treatment trial for a defined period. NICE guidance suggests that reversibility testing should not be routine if clinical features and spirometry are strongly suggestive of COPD.[9]
- Slowly progressive respiratory symptoms in a middle-aged or elderly smoker are most likely to be due to COPD but it is not uncommon for patients to have both conditions - more likely if symptoms have onset prior to the age of 35 years and if symptoms vary in severity.

Further reading

- Spirometry Handbook; National Asthma Council, Australia
- Johnson JD, Theurer WM; A stepwise approach to the interpretation of pulmonary function tests. Am Fam Physician. 2014 Mar 1;89(5):359-66.
- Spirometry for Health Care Providers; Global Initiative For Chronic Obstructive Lung Disease (GOLD), 2010

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