Miranda A Paraskeva
Brigitte M Borg
Matthew T Naughton

Spirometry

This article forms part of our 'Tests and results' series for 2011 which aims to provide information about common tests that general practitioners order regularly. It considers areas such as indications, what to tell the patient, what the test can and cannot tell you, and interpretation of results.

Spirometry measures the flow and volume of air entering and leaving the lungs. It is used to assess ventilatory function and differentiates between normality and diseases causing obstructive and possibly restrictive defects.

Keywords: asthma; respiratory tract diseases; pulmonary disease, chronic obstructive; respiratory tract diseases

Spirometry should be performed early in the assessment of a patient presenting with symptoms of ventilatory dysfunction. Common indications are listed in *Table 1*.

Precautions

While spirometry is generally considered to be safe, high airway and intrathoracic pressures are generated during the test, hence it is not recommended in the following settings:[1]

- if the patient is unable to cooperate or sit upright
- recent pneumothorax (within 6 weeks)
- unstable angina or recent myocardial infarction (within 4 weeks)
- haemoptysis (within 48 hours)
- recent abdominal, thoracic or eye surgery (within 6 weeks)
- thoracic, aortic or cerebral aneurysm
- suspected or confirmed communicable infectious disease (eg. tuberculosis or influenza).

Patient preparation

Most patients are able to complete the test when coached by a trained respiratory technician. An interpreter is recommended in patients with a limited understanding of English.

The patient should:[2]

- attempt to withhold inhaled medications, especially short acting (for 4–6 hours) and long acting (for 12–24 hours) bronchodilators
- not smoke or perform strenuous exercise on the day of the test
- not consume alcohol or eat a large meal within 4 hours of the procedure
- wear unrestrictive, loose clothing during the procedure.

How to do the test

With the patient sitting upright on a chair or in standing position, and with their lips sealed tightly around a spirometer mouthpiece, the patient is asked to exhale as hard and as fast as they can from a position of maximal inhalation until they cannot blow out any more.

How does the test work?

Spirometry provides three measurements:

- Forced vital capacity (FVC) is the maximal volume of air that can be forcibly expelled from the lungs from a position of maximal inhalation. It indicates lung volume
- Forced expiratory volume in 1 second (FEV_1) is the maximal volume of air exhaled in the first second of an FVC manoeuvre. In individuals with normal lung function this is 75–80% of FVC. FEV_1 reflects the mechanical properties of the large and medium sized airways
- Forced expiratory ratio (FEV_1/FVC or FER%) is the ratio of FEV_1 to FVC, expressed as a percentage. It assists with distinguishing obstruction from possible restriction when FEV_1 is reduced. If restriction is suspected, further testing with static lung volumes may be required.

Flow volume loop

The flow volume loop (*Figure 1*) illustrates the relationship between flow and volume as a maximal effort from maximal inspiration to maximal expiration (positive flows) and from maximal expiration to maximal inspiration (negative flows). The shape of the loop depends on the mechanical properties of the lungs and may assist in the diagnosis of ventilatory dysfunction.

Table 1. Indications for spirometry[4]
The evaluation of symptoms, signs or abnormal investigations*
Symptoms: chronic cough, dyspnoea, wheeze, orthopnoea, sputum production
Signs: chest deformity (barrel chest), cyanosis, prolonged expiration, wheeze/stridor, unexplained crackles
Investigations: hypoxaemia, hypercapnia, polycythaemia, abnormal chest X-ray
To follow the course of disease and assess prognosis
To screen at risk individuals**
History of tobacco smoking
Occupational exposure
Use of drugs with potential pulmonary toxicity
Neuromuscular diseases (eg. motor neurone disease, Guillain-Barre syndrome)
To assess preoperative risk in selected patients
To monitor therapy
* Medicare rebate available for pre- and post-bronchodilator spirometry
** Screening for employment or recreational activities is not covered by Medicare

Table 2. Causes of obstructive and restrictive impairment on spirometry	
Restrictive lung disease	**Obstructive lung disease**
Pulmonary fibrosis	Chronic obstructive pulmonary disease (COPD)
Neuromuscular disorders	Asthma
Congestive cardiac failure	Bronchiectasis/cystic fibrosis
Sarcoidosis	Cystic fibrosis
Obesity	Bronchiolitis
	α1 – antitrypsin deficiency

Interpretation of results

Simplistically, ventilatory impairment diagnosed on spirometry can be divided into:

- obstructive
- restrictive, and
- mixed defects (*Table 2*).

Obstructive ventilatory defect

Obstructive airways disease is characterised by expiratory airflow limitation. There is a disproportionate reduction in FEV_1 as compared to FVC (decreased FEV_1/FVC ratio).

The typical obstructive flow volume loop shows concavity of the expiratory limb (*Figure 2*).

Lung volume determination is rarely used to confirm obstructive disease. Assessment of bronchodilator reversibility is usually relevant.

Bronchodilator reversibility

Significant bronchodilator reversibility is defined by a 12% and greater than 200 mL increase in either FEV_1 or FVC (or both).[3] It is assessed by the administration of a short acting beta 2 agonist and repeating spirometry after around 10 minutes.[4] Failure to respond does not preclude clinical benefit from bronchodilators.

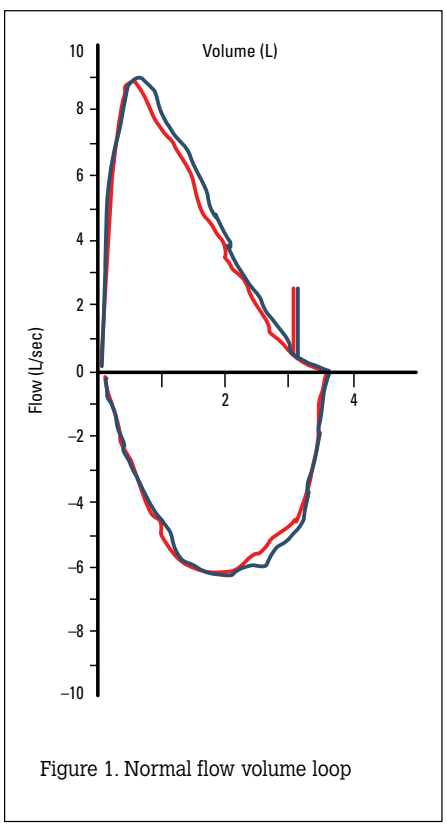


Figure 1. Normal flow volume loop

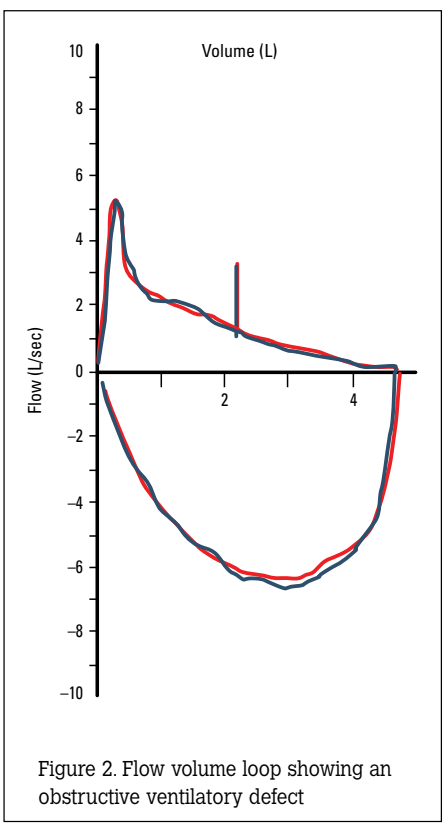


Figure 2. Flow volume loop showing an obstructive ventilatory defect

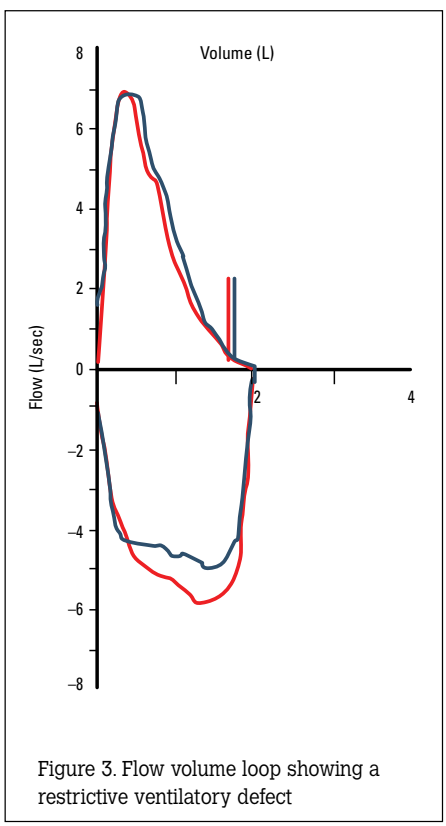


Figure 3. Flow volume loop showing a restrictive ventilatory defect

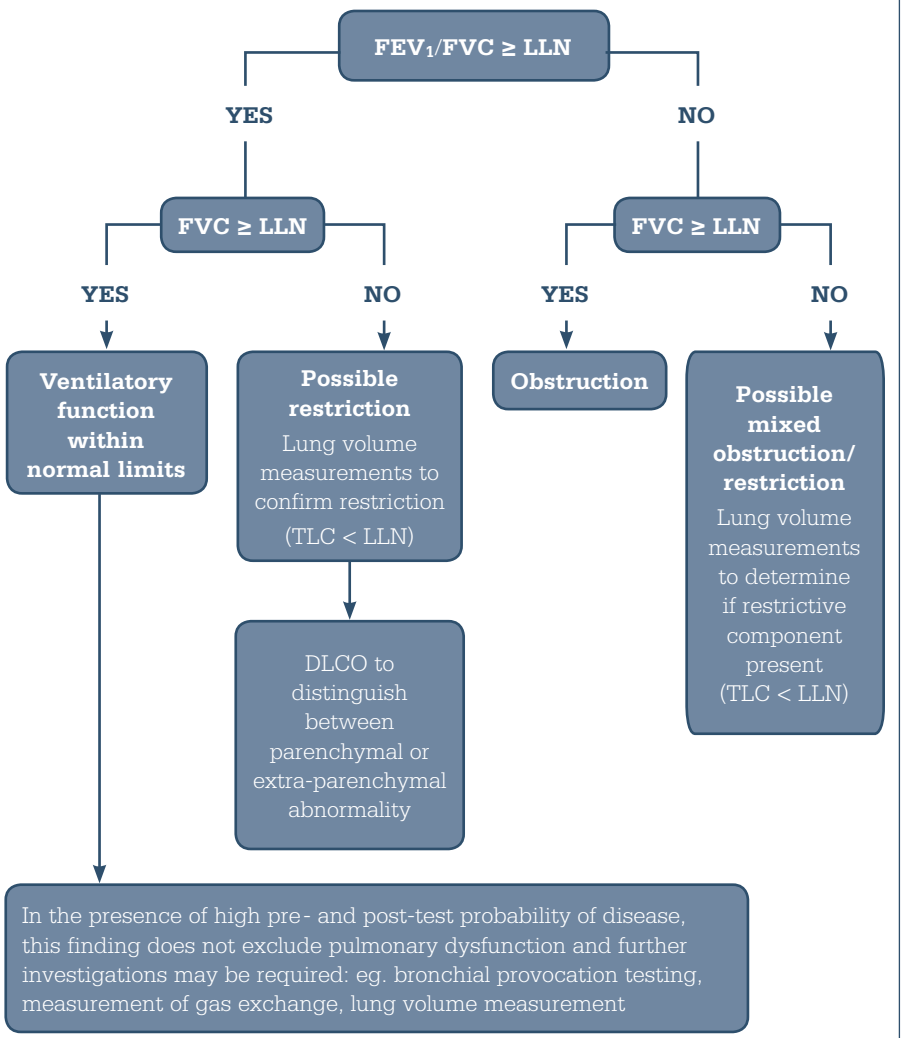


Figure 4. Interpretative strategy for spirometry
TLC = total lung capacity: unable to be measured with spirometry
LLN = lower limit of normal range (5th percentile)
DLCO = diffusing capacity of the lung for carbon monoxide

A component of reversible obstruction indicates the presence of obstructive disease or suboptimal symptom control in patients on treatment for obstructive disease. Considerations should include checking inhaler technique, discussing concordance, and considering increasing medication dose. No current evidence of obstruction indicates good control if the patient is on active treatment. If there is no evidence of obstruction, and the patient is not on treatment, and has a suggestive history for respiratory dysfunction, other tests may be indicated (eg. bronchial provocation test, gas exchange and lung volumes).

Restrictive ventilatory defect

Restrictive lung disease cannot be categorically diagnosed by spirometry alone. It is characterised by reduction in the FVC with a normal or increased FEV_1/FVC ratio. Such a result should trigger a diagnostic work up to rule out restrictive lung disease, including more detailed lung volume measurement.

The flow volume loop tends to be tall and narrow with steep end expiratory phase (*Figure 3*).

Next steps

An obstructive ventilatory defect requires no further confirmatory pulmonary function testing.

In conjunction with history, examination and other investigation modalities, a diagnosis should be made and best practice clinical guidelines followed (eg. the COPD-X Plan or Asthma Management Handbook, see *Resources*).

If spirometry suggests a restrictive ventilatory defect or restrictive component (eg. mixed defect), then further evaluation with static lung volumes is needed to confirm restriction. Diffusion capacity helps distinguish parenchymal from extraparenchymal disease. *Figure 4* provides an algorithm for further investigation.

What if spirometry is negative or inconclusive?

A normal spirometry result does not exclude pulmonary disease. If there is a high clinical suspicion of lung disease the patient should be referred for more complex lung function testing in conjunction with other investigations (eg. radiological imaging). Referral to a respiratory physician may be considered.

Case study

You review the spirometry results of a female exsmoker, 38 years of age, who presented to her doctor with shortness of breath and wheeze. As the differential diagnosis was asthma, pre- and post-bronchodilator spirometry was requested (*Figure 5*).

Resources

- Johns DJ, Pierce R. Pocket guide to spirometry. 2nd edn. North Ryde: McGraw-Hill 2007
- For spirometry training courses: www.anzsrs.org.au/escourses.html
- The COPD-X Plan: Australian and New Zealand Guidelines for the management of Chronic Obstructive Pulmonary Disease 2010: www.copdx.org.au/contents
- Asthma Management Handbook 2006: www.nationalasthma.org.au.

Authors

Miranda A Paraskeva MBBS, is a respiratory registrar, Department of Allergy, Immunology and Respiratory Medicine, Alfred Hospital, Melbourne, Victoria. m.paraskeva@alfred.org.au

Brigitte M Borg BAppSc, CRFS, is Senior Respiratory Scientist, Department of Allergy, Immunology and Respiratory Medicine, Alfred Hospital, Melbourne, Victoria

Matthew T Naughton MD, FRACP, is a respiratory and sleep physician, Department of Allergy, Immunology and Respiratory Medicine, Alfred Hospital and Monash University Melbourne, Victoria.

Respiratory function report				Name:	Patient X	
				ID No:	ABC123	
				Date of birth:	31/7/1967 (38)	
				Gender:	Female	
Ht (cm):	175.8	Smoking Hx:	Ex	Date	13/8/2005	
Wt (kg):	57	Pack years:	9	Time	11:30	
BMI (kg/m^2):	18					
Referring Dr:	Johns					

Clinical note: ?asthma

Spirometry parameters and their units

Describes the range in which we are confident 95% of the normal population lie

Results before administration of a bronchodilator

The baseline value as a percentage of the mean predicted value. May assist with assigning severity of ventilatory defect

Results following administration of a bronchodilator

Percentage change between baseline and post BD values

Spirometry	Normal range	Baseline	% predicted	Postbronchodilator	% change
FEV_1 (L)	>2.62	3.00	92%	3.70#	+23%#
FVC (L)	>3.13	4.51*	114%	4.85	+8%
FEV_1/FVC (%)	>71%	67%*	80%	76	

Technical comments:

Provides information regarding quality and validity of test results

Test performance was good

Report:

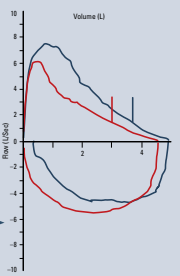
There is an obstructive ventilatory defect.* There was a significant response to inhaled bronchodilator.# Results are consistent with a diagnosis of asthma^

Flow volume curve. Positive flows represent expiration, negative flows represent inspiration.

Red – baseline

Blue – post BD

The tick represents the location of FEV_1



* Baseline FEV_1/FVC is below the lower limit of normal (normal range >71%). FVC is within normal limits (>3.13); indicates obstruction

\# There was a >12% increase in FEV_1 (23%) that was also >200 mL (700 mL). Therefore the response to inhaled bronchodilator is significant

^ Fully reversible obstructive pattern on spirometry is consistent with suboptimally controlled asthma

Figure 5. Spirometry results of Case study patient

Conflict of interest: none declared.

References

1. Cooper BG. An update on contraindications for lung function testing. Thorax 2010 [Epub ahead of print].
2. Miller MR, Crapo R, Hankinson J, et al. General considerations for lung function testing. Eur Respir J 2005;26:153–61.
3. Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J 2005;26:948–68.
4. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. Eur Respir J 2005;26:319–38.

correspondence **afp@racgp.org.au**