

Spirometry

for health professionals

Spirometry is the most commonly used respiratory function test for assessing respiratory disease worldwide. The principles of spirometry are relatively simple and testing should produce good quality data provided the points raised in this sheet are taken into account.

Training

Any GP, practice nurse or asthma educator planning to provide spirometry should attend a professional spirometry course. This will enable them to optimise their knowledge of spirometry, their ability to interpret results, and their ability to produce good-quality recordings. Formal courses in spirometry are currently available at Green Lane and Christchurch Hospitals.

Equipment

The quality of spirometry results is dependent on the equipment used. When choosing from the wide variety of portable spirometers available for use in primary care, take the following factors into account :

- cost should not be the only consideration - the accuracy of the instrument is paramount.
- ease of use.
- suitability of software.
- the need for a visual display in real time of the flow volume graph.
- results should be reported at BTPS conditions (adjusted for body temperature).
- the spirometer should either incorporate a printer into the device or be able to be connected to an external printer.
- the equipment should be able to be dismantled and reassembled for cleaning and disinfection without damaging the components.
- the distributor should be able to provide good, reliable backup support - including maintenance and training - and guarantee the availability of parts.
- the ability to choose suitable reference equations for comparing results is desirable.

Indications for spirometry

- detection of normal or abnormal lung function
- quantifying extent of reduced lung function
- following progression of disease
To assess whether :
 - decline in lung function is greater than that of normal population
 - patient is having an acute exacerbation (and, if so, gauging its severity)
 - to consider referral for home oxygen
- differentiation between asthma and COPD
- measuring effects of occupational exposure
- measuring efficacy of treatment (particularly to oral/inhaled steroids)
- undertaking preoperative assessment
- evaluating impairment or disability

See the Table on page 2 for recommended portable spirometers.

Equipment use and maintenance

Beware of statements from sales people claiming their spirometer never needs calibrating. There is a difference between being able to adjust the calibration of a spirometer and simple verification of the calibration. Flow-based spirometers should be checked with a calibrated syringe (usually 3L) before use at different flow rates within the physiological range of spirometry parameters.

In recent years it has become common practice to use a single-use barrier filter to protect the equipment from contamination. There is some evidence they may reduce the risk of cross-infection and that their use is cost-effective. Alternatively, cleaning the spirometers between tests would be indicated. Barrier filters should have a low dead space and low resistance to flow.

Mouthpieces, nose clips, tubing and equipment on the patient side of a filter should be replaced with clean components between patients. The spirometer should also be cleaned at least once daily to remove particulate matter and moisture.

Undertaking the test

Tests should be performed when the patients are clinically stable and free from infection. Patients should not have taken short acting bronchodilators in the previous six hours, long acting beta agonists in the previous 12 hours, or sustained release theophyllines in the preceding 24 hours.

A good test depends on the operator developing a rapport with the subject and “coaching” them to produce a maximum effort. The subject must have the physical ability to exhale forcefully and be able to comprehend the instructions.

Spirometric values should be measured before and after an adequate dose of inhaled bronchodilator. The dose selected should be high on the dose/response curve and is usually given by nebuliser to be certain it has been inhaled. An alternative, less convenient technique, would be to give a similar dose with six to 12 inhalations from a metered dose inhaler and large volume spacer.

Recommended doses would be:

- before and 15 minutes after: 2.5-5mg nebulised salbutamol, or 5-10mg terbutaline, or
- before and 30 minutes after: 500µg nebulised ipratropium bromide, or
- before and 30 minutes after: salbutamol and ipratropium bromide in combination, eg Combivent.

The manoeuvre requires a complete inspiration followed by a forced expiration to residual volume (for a minimum of six seconds). The subject should be seated or standing and the use of a nose clip is recommended.

Three technically acceptable results should be recorded : two should be reproducible within 200ml of the FVC and FEV₁ (see definitions on page 3); the peak flow rate should be reproducible within 10 per cent.

Each manoeuvre should have a sharp takeoff with no hesitation, otherwise all measurements based on flow are underestimated and therefore invalid. The end of test criteria should be assessed carefully to be sure the subject has exhaled completely – hence the necessity of having a “real time” display of the manoeuvre during testing.

Recommended portable spirometers			
The spirometers listed below include a real time graphical display of the spirometry manoeuvre and pre- and post- bronchodilator response. Current inclusion of FEV ₆ as indicated. Most manufacturers plan to include FEV ₆ in the future. All spirometers can be linked into a PC for data storage and in some cases the operator can choose the manoeuvre to store.			
Spirometer	Manufacturer	Price	Distributor
SpiroPro (FEV ₆ parameters included Printer not included)	SensorMedics	\$4,100.00 + GST	CARE Medical 0800 333 444 sales@caremed.co.nz
SpiroPro (SpiroPro windows software CD included)	SensorMedics	\$4,450.00 + GST	
Spirobank G (HP printer and Winspiro software CD included)	MIR	\$2,500.00 + GST	McLaren Medical Ltd 0800 626 334 handfield@mcmcd.co.nz
Spirolab II (Built in printer, FEV ₆ parameters and Winspiro software CD included)	MIR	\$4,500.00 + GST	
Microloop (SPIDA windows software included Printer not included)	Micro Medical	\$3,379.45 + GST	Cass Distributors 0800 122 277 info@cass.co.nz
Microlab (Built in printer, SPIDA windows software not included)	Micro Medical	\$4,351.65 + GST	
Microlab (Built in printer, SPIDA windows software included)	Micro Medical	\$5,313.20 + GST	

More sophisticated spirometers may have incentive displays for subjects and the operator to monitor. The operator should comment on the technical adequacy of the final results if the subject was unable to comply with all aspects of the forced expiratory manoeuvre.

Interpreting results

There are many published reference values for the interpretation of spirometry results in the medical literature. It is important that the equations chosen for comparing measured results are generated using age-matched normal subjects and similar equipment.

The results of a spirometry test can be grouped into three categories: normal lung function, obstructive, or restrictive (see figures 1–4, page 4). Extra information can be gained by looking at the shape of the flow volume curve. This can be particularly important in helping to differentiate between a restrictive pattern and an early end of test.

Steps for interpretation are as follows (see box below for definitions of terms used) :

1. Choose a statistically acceptable lower limit of normal. Evaluate and comment on test quality. Use FVC, FEV₁ and FEV₁/FVC percentage as the primary guides for interpretation. (Increasing the number of variables in the interpretation increases the incidence of false positive results.)
2. Values well above or below the lower limits of normal can be interpreted with confidence. Interpret borderline values with caution, using clinical information to make decisions.
3. The primary indicator of airflow obstruction is a reduced FEV₁/FVC percentage.

Spirometry – definitions

FVC (L)	forced vital capacity - volume of air exhaled after full inspiration
FEV₆ (L)	forced expiratory volume - measured six seconds after commencement of expiration - may be used as a surrogate for FVC
FEV₁ (L)	forced expiratory volume - measured one second after commencement of expiration
FEV₁/FVC	ratio of the VC exhaled in one second
FEV₁/FEV₆	ratio of FEV ₆ exhaled in one second - may be used as a surrogate for FEV ₁ /FVC
PEFR (L/sec)	peak expiratory flow rate
FEF₂₅₋₇₅ (L/sec)	forced expiratory flow rate - during the middle half of the expiration
FET (seconds)	forced expiratory time

Note: All spirometry parameters must be converted to standardised BTPS conditions. This is a temperature correction converting the result from ambient conditions to 37°C - ie the volume of air in the lung at body temperature. If FEV₆ is used the reference values must include FEV₆

4. Once obstruction is diagnosed, classify the severity using FEV₁ expressed as a percentage of the predicted value.
5. Determine the response to bronchodilator therapy.
6. A restrictive pattern may be cautiously diagnosed from the spirometry examination when VC is reduced and FEV₁/FVC is normal. However, the definitive finding of a restricted pattern is a reduced total lung capacity (TLC) which can only be measured in a lung function laboratory.
7. The severity of restriction should be based on TLC if that value is available, and otherwise from VC.
8. Restriction cannot be diagnosed from the spirometric examination in the presence of moderate to severe obstruction.

Bronchodilator response

The preferred outcome measure is the change in FEV₁ because its reproducibility is well known and is much more accurate than for peak flow.

The following is a guide to interpretation of results after bronchodilator therapy.

1. An increase in FEV₁ that is both >200ml and shows a 15 per cent increase over the pre-bronchodilator value is significantly greater than the natural variability of the FEV₁, and is the most established definition of reversibility.
2. The post-bronchodilator FEV₁ provides information about prognosis and can be used as a marker against which to assess future treatment.
3. A negative FEV₁ response does not preclude benefit from bronchodilators in terms of improved walking distance or a reduction in the perception of breathlessness.

Spirometry values should be measured before and at the end of a trial of oral prednisone (eg 20–30mg per day) taken for two weeks, or a course of inhaled steroid (eg beclomethasone 500µg twice daily or equivalent) taken for six weeks. The criteria for an FEV₁ response are as for bronchodilators.

A less studied alternative is to use the change in the mean PEF measured over the first five days and last five days of a steroid course, accepting a rise of 20 per cent in mean PEF as significant. Results of reversibility testing should be clearly documented in the notes and thus be easily available for future reference.

A positive response to corticosteroids justifies prescription of regular inhaled corticosteroids for six months initially to assess the clinical benefits over time. The response to bronchodilators or corticosteroids can set a target against which to compare future therapy.

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Figure 1. Normal spirometry

Age: 46 Height (cm): 166 Weight (kg): 57.0 BMI: 20.69 Gender: female

	Ref	Pre Meas	Pre %Ref	Post Meas	Post % Chg	CI	LLN
FEV ₁ (L)	2.70	2.94	109			0.84	
FVC (L)	3.52	3.63	103			0.99	
FEV ₁ /FVC %	76	81					
PEF (L/sec)	6.20	8.30	134			2.84	
FEF ₂₅₋₇₅ (L/sec)	3.79	4.47	118			1.82	
FET _{100%} (sec)		15.96					
FEV ₆	3.69	3.74	94				2.98
FEV ₁ /FEV ₆	83	85					74

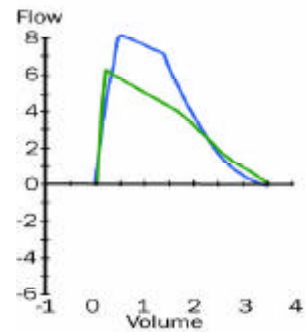


Figure 2. Restrictive pattern. FEV₁/FVC ratio elevated. Reduced FVC at 66 per cent reference value

Age: 49 Height (cm): 167 Weight (kg): 146.5 BMI: 52.53 Gender: male

	Ref	Pre Meas	Pre %Ref	Post Meas	Post % Chg	CI	LLN
FEV ₁ (L)	3.24	2.27	70			1.00	
FVC (L)	4.30	**2.85	**66			1.36	
FEV ₁ /FVC %	75	80					
PEF (L/sec)	8.05	7.59	94			3.87	
FEF ₂₅₋₇₅ (L/sec)	4.09	2.72	67			2.67	
FET _{100%} (sec)		14.86					
FEV ₆	4.23	2.69	64				3.43
FEV ₁ /FEV ₆	80	84					72

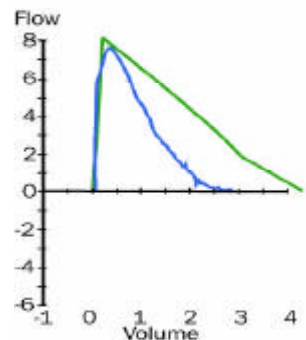


Figure 3. Obstructive pattern with clinically significant bronchodilator response. FEV₁ percentage reference shows an improvement from 64 to 92 per cent

Age: 59 Height (cm): 172 Weight (kg): 92.0 BMI: 31.10 Gender: male

	Ref	Pre Meas	Pre %Ref	Post Meas	Post % Chg	CI	LLN
FEV ₁ (L)	3.11	**2.00	**64	2.85	42	1.00	
FVC (L)	4.35	3.40	78	4.10	21	1.36	
FEV ₁ /FVC %	72	59		69			
PEF (L/sec)	8.17	4.45	54	6.81	53	3.87	
FEF ₂₅₋₇₅ (L/sec)	4.06	**1.23	**30	2.24	82	2.67	
FET _{100%} (sec)		7.46		10.62	42		
FEV ₆	4.22	3.40	81	3.97	17		3.34
FEV ₁ /FEV ₆	79	59		72			70

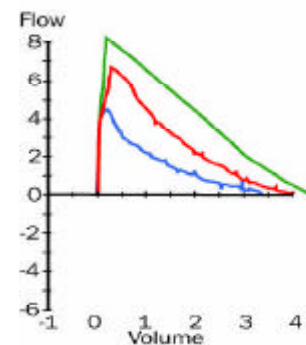
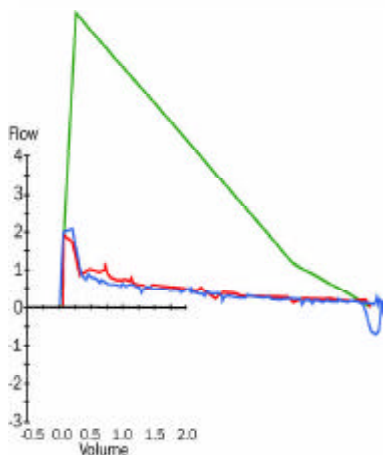


Figure 4. Severe obstructive pattern with no bronchodilator response. FEV₁/FVC ratio 22 per cent. FEV₁ 36 per cent of reference value. Note expiratory time of 20 seconds

Age: 78 Height (cm): 175 Weight (kg): 77 BMI: 25.14 Gender: male

	Ref	Pre Meas	Pre %Ref	Post Meas	Post % Chg	CI	LLN
FEV ₁ (L)	2.59	**0.93	**36	**0.94	1	1.00	
FVC (L)	4.02	4.20	104	4.06	-3	1.36	
FEV ₁ /FVC %	67	22		23			
PEF (L/sec)	7.75	**2.58	*33	**2.23	-13	3.87	
FEF ₂₅₋₇₅ (L/sec)	3.57	**0.28	**8	**0.29	4	2.67	
FET _{100%} (sec)		20.64		20.56	-0		
FEV ₆	3.67	2.51	68	2.62	4		2.79
FEV ₁ /FEV ₆	77	37		36			68



green=REF; blue=PRE; red=POST