Spirometry practical guide and test interpretation
Use of spirometry pre- lung surgery

Dr Paula Agostini PhD, Specialist Physiotherapist
Heart of England NHS Foundation Trust

Feb 2018

Acknowledgements: Sarah Cameron, HEFT CF Dept

What is spirometry?

- '*Method of assessing lung function by measuring the volume of air that the patient is able to expel from the lungs after a maximal inspiration'* (NICE 2004)
- Differentiates - obstructive/restrictive disorders
- Most effective way of determining severity (not signs/symptoms alone)
- MRC dyspnoea scale/QOL

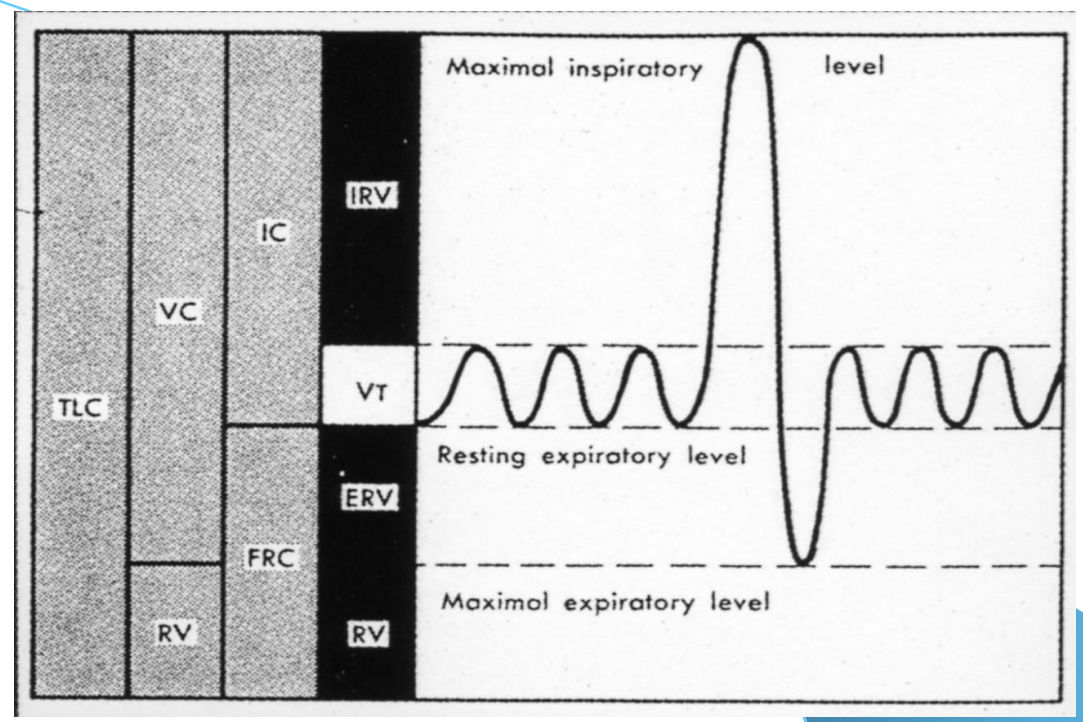
Training

- '*All healthcare professionals managing patients with COPD should be competent in the interpretation of the results of spirometry and all healthcare professionals performing spirometry should have undergone appropriate training and keep their skills up to date*' (NICE 2004)

- Association of Respiratory Technology and Physiology (ARTP)/BTS

  → Certificate of Competence

Lung Volumes



Types of spirometer

- Many different types £300 - £3000
- Hand held - FEV_1 & FVC readings
- Advanced - visual/printable traces
- Electronic - flow-volume curve
- Calculate %age predicted normal values
- Reports - defects, severity

Care of spirometers

- Ensure good care/maintenance of your spirometer → accurate & reproducible results
- Keep clean
- Accuracy checked regularly (manufacturers recommendations)
- Calibration (accuracy check) with large volume syringe
- Re-calibration by manufacturer

- NICE guideline emphasises importance of maintaining accuracy and recommends that spirometry services should be supported by quality control processes

Maintaining accuracy

- Patient technique - most common reason for inconsistent readings

To detect errors observe patient and trace:

- Inadequate/incomplete inhalation
- Lack of 'blast' effort during exhalation
- Additional breath taken during manoeuvre
- Poor seal with mouthpiece
- Slow start to forced exhalation
- Exhalation stops before complete expiration
- Some exhalation through the nose
- Coughing

Preparing the patient

- Comfortable/ seated
- Explain purpose/demonstrate technique
- Allow practice attempts
- Encourage full exhalation
- Limit total attempts to 8 or less/session
- 30 seconds rest between blows

Information:

- Age, gender, height
- Adjust normal values (Asian/Afro-Carribean)
- Note ??recent bronchodilator/exacerbation/pain

The manoeuvre

- Disposable one-way mouthpiece
- Instruct patient to 'take the deepest breath po it, then place the filter into their mouth with a tig..t ...de by their lips.'

- Forced expiration - hard/fast as possible until no further air to expel (bleep)
  → severe COPD up to 15 seconds
- Avoid pursed-lips
- Nose clip/hold nose

- Repeat procedure - 3 readings (best 2 within 100ml/5%)
- Assess quality of each blow

The manoeuvre – in brief

- Full inspiration
- Inspiratory hold
- Avoid pursed-lips
- Forced expiration
  - hard/fast as possible
  - until no further air to expel
    - (severe COPD up to 15 seconds)
- Repeat procedure
  - 3 readings (best 2 within 100ml /5%)

Interpreting results

- Best of 3 consistent readings (FEV_1 & FVC)
- Borderline normal results - repeat in few months to confirm diagnosis (especially > 75 years)

Abnormality detected if any of following recorded:

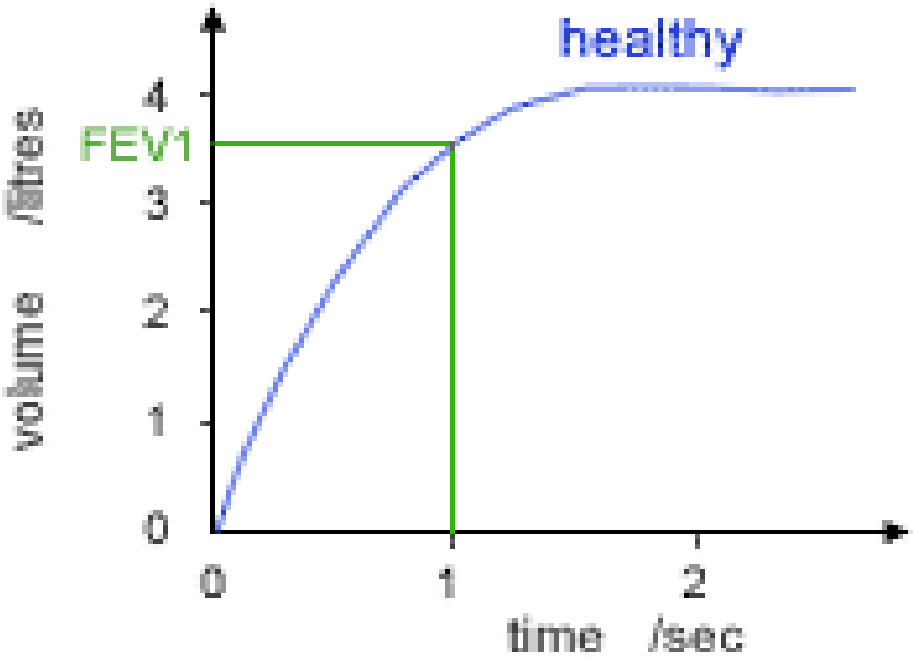
- FEV_1 <80% predicted normal
- FVC <80% predicted normal
- FEV_1/FVC ratio <0.7

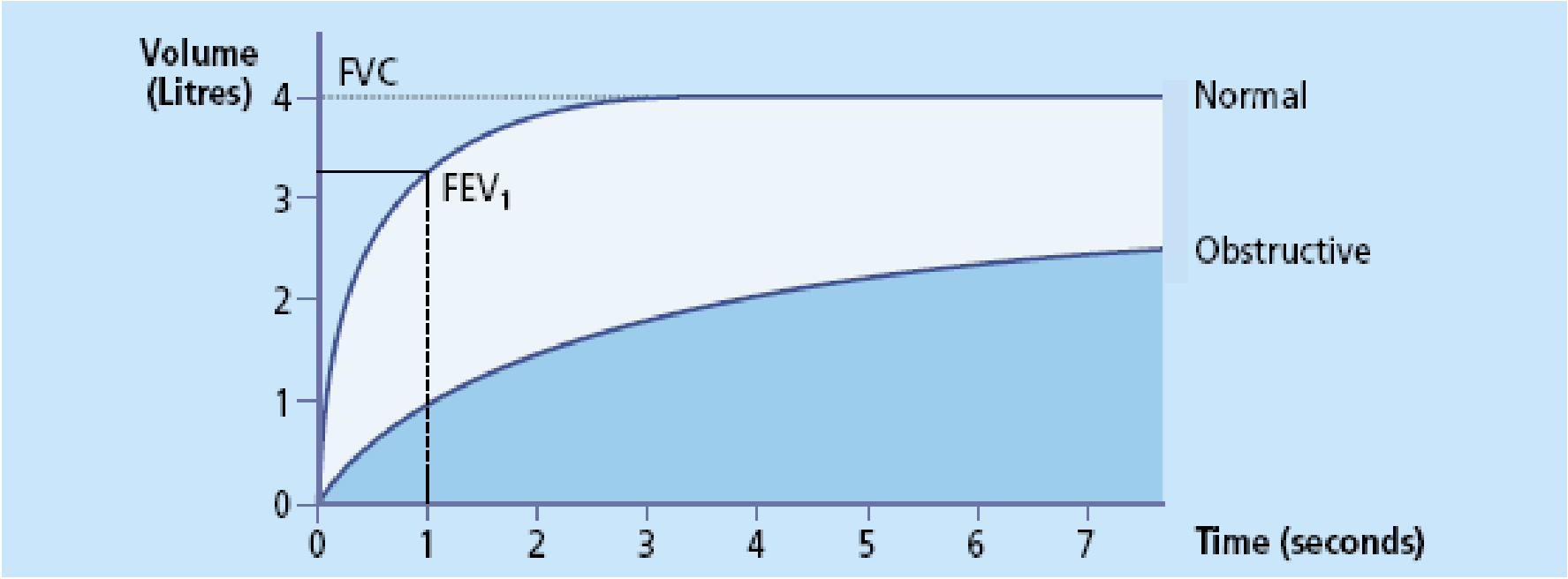
Patient: 45 year old woman, height 5'3"

FEV_1	Reading	1.43	x 100% = 55% of predicted normal
	Predicted value	2.60	
FVC	Reading	2.5	x 100% = 82.5% of predicted normal
	Predicted value	3.03	
$\frac{FEV_1}{FVC}$	Reading	$\frac{1.43}{2.5}$	= 0.57

- Mild airflow obstruction → FEV_1 is between 50 and 80% of predicted normal & FEV_1/FVC is <0.7

Normal spirometry





- FEV_1
- FVC
- FEV_1/FVC
- VC
- FEV_1/VC

- FEV_1/FVC values based on age/gender/height
- Predicted values lower in non-caucasions

These values apply to Caucasians.
Reduce values by 7% for Asians and by 13% for Afro-Caribbeans.

Male			Height						
			5'3" 160cm	5'5" 165cm	5'7" 170cm	5'9" 175cm	5'11" 180cm	6'1" 185cm	6'3" 190cm
Age	38–41 years	FVC	3.81	4.10	4.39	4.67	4.96	5.25	5.54
		FEV_1	3.20	3.42	3.63	3.85	4.06	4.28	4.49
	42–45 years	FVC	3.71	3.99	4.28	4.57	4.86	5.15	5.43
		FEV_1	3.09	3.30	3.52	3.73	3.95	4.16	4.38
	46–49 years	FVC	3.60	3.89	4.18	4.47	4.75	5.04	5.33
		FEV_1	2.97	3.18	3.40	3.61	3.83	4.04	4.26
	50–53 years	FVC	3.50	3.79	4.07	4.36	4.65	4.94	5.23
		FEV_1	2.85	3.07	3.28	3.50	3.71	3.93	4.14
	54–57 years	FVC	3.39	3.68	3.97	4.26	4.55	4.83	5.12
		FEV_1	2.74	2.95	3.17	3.38	3.60	3.81	4.03
	58–61 years	FVC	3.29	3.58	3.87	4.15	4.44	4.73	5.02
		FEV_1	2.62	2.84	3.05	3.27	3.48	3.70	3.91
	62–65 years	FVC	3.19	3.47	3.76	4.05	4.34	4.63	4.91
		FEV_1	2.51	2.72	2.94	3.15	3.37	3.58	3.80
	66–69 years	FVC	3.08	3.37	3.66	3.95	4.23	4.52	4.81
		FEV_1	2.39	2.60	2.82	3.03	3.25	3.46	3.68

For men over 70 years predicted values are less well established but can be calculated from the equations below (height in cms; age in years):

FVC = (0.0576 x height) - (0.026 x age) - 4.34 (SD: ± 0.61 litres)
FEV_1 = (0.043 x height) - (0.029 x age) - 2.49 (SD: ± 0.51 litres)

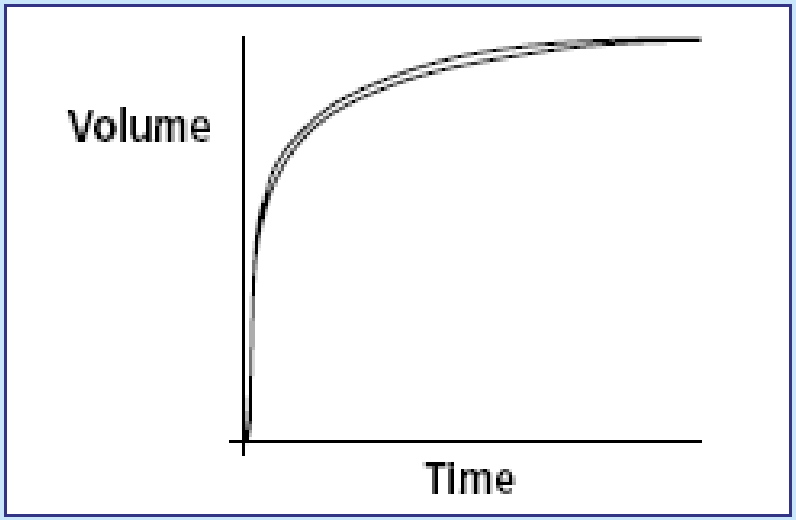
Female			Height						
			4'11" 150cm	5'1" 155cm	5'3" 160cm	5'5" 165cm	5'7" 170cm	5'9" 175cm	5'11" 180cm
Age	38–41 years	FVC	2.69	2.91	3.13	3.35	3.58	3.80	4.02
		FEV_1	2.30	2.50	2.70	2.89	3.09	3.29	3.49
	42–45 years	FVC	2.59	2.81	3.03	3.25	3.47	3.69	3.91
		FEV_1	2.20	2.40	2.60	2.79	2.99	3.19	3.39
	46–49 years	FVC	2.48	2.70	2.92	3.15	3.37	3.59	3.81
		FEV_1	2.10	2.30	2.50	2.69	2.89	3.09	3.29
	50–53 years	FVC	2.38	2.60	2.82	3.04	3.26	3.48	3.71
		FEV_1	2.00	2.20	2.40	2.59	2.79	2.99	3.19
	54–57 years	FVC	2.27	2.49	2.72	2.94	3.16	3.38	3.60
		FEV_1	1.90	2.10	2.30	2.49	2.69	2.89	3.09
	58–61 years	FVC	2.17	2.39	2.61	2.83	3.06	3.28	3.50
		FEV_1	1.80	2.00	2.20	2.39	2.59	2.79	2.99
	62–65 years	FVC	2.07	2.29	2.51	2.73	2.95	3.17	3.39
		FEV_1	1.70	1.90	2.10	2.29	2.49	2.69	2.89
	66–69 years	FVC	1.96	2.18	2.40	2.63	2.85	3.07	3.29
		FEV_1	1.60	1.80	2.00	2.19	2.39	2.59	2.79

For women over 70 years predicted values are less well established but can be calculated from the equations below (height in cms; age in years):

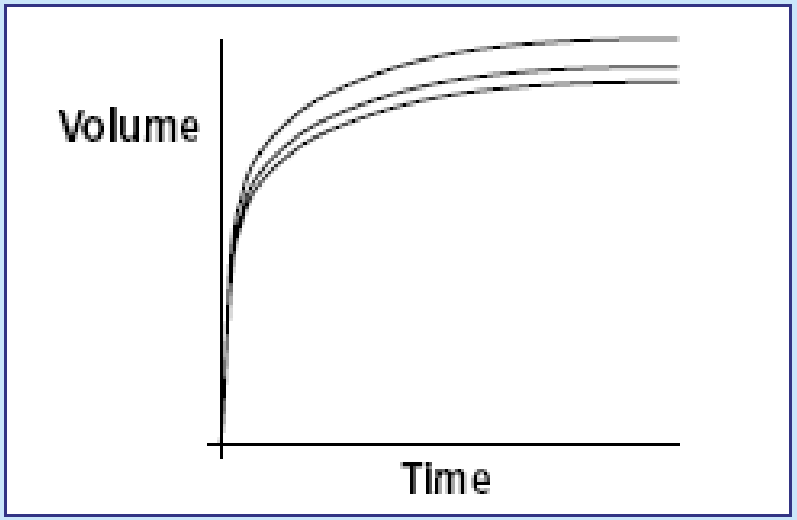
FVC = (0.0443 x height) - (0.026 x age) - 2.89 (SD: ± 0.43 litres)
FEV_1 = (0.0395 x height) - (0.025 x age) - 2.60 (SD: ± 0.38 litres)

Consistent & inconsistent volume-time curves

Three consistent volume-time curves are required of which the best two curves are within 100ml or 5% of each other.

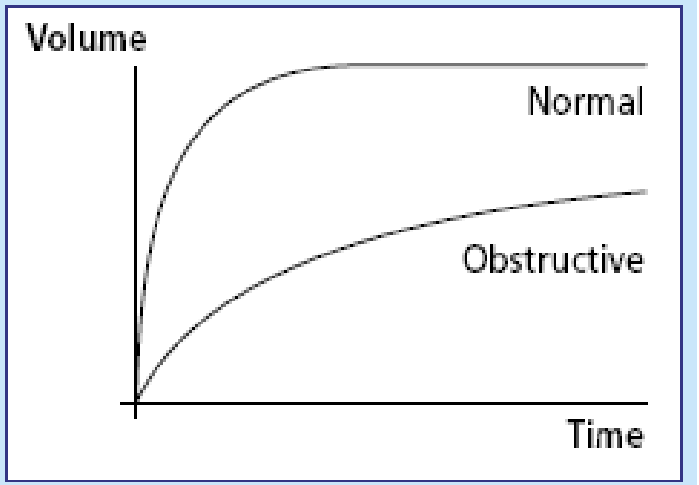


Consistent: Three acceptable and consistent traces.



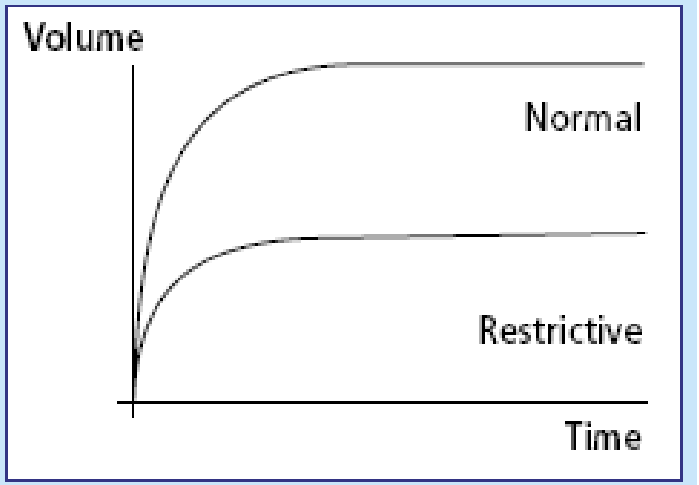
Inconsistent: Although each trace is technically acceptable, they are inconsistent.

Identifying abnormalities



Obstructive disorder

- FEV_1 reduced (<80% predicted normal)
- FVC usually reduced but to lesser extent than FEV_1
- FEV_1/FVC ratio reduced (<0.7)



Restrictive disorder

- FEV_1 reduced (<80% predicted normal)
- FVC reduced (<80% predicted normal)
- FEV_1/FVC ratio normal (>0.7)

Obstruction

- Oedema
- Bronchospasm
- Floppy airways- reduced elastic recoil (emphysema/age)
- Tumour
- UAO

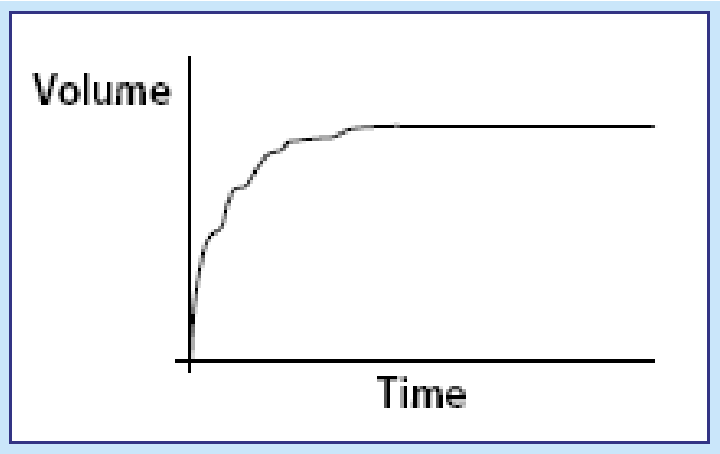
Restriction

- Lung
- Pleural
- Skeletal
- Soft tissue
- Abdominal
- neurological

Trouble shooting

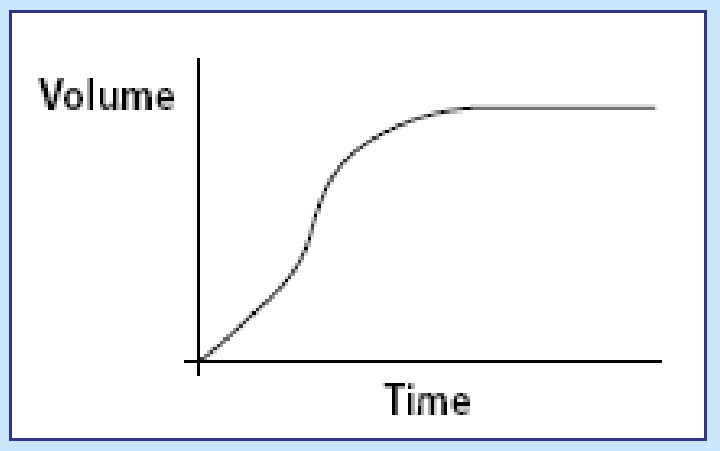
- Slow start
- Cough
- Poor understanding/ submaximal effort- pain
- Fatigue/bronchospasm
- Early end of blow
- Glottic closure
- Leak- mouthpiece

Identifying abnormalities



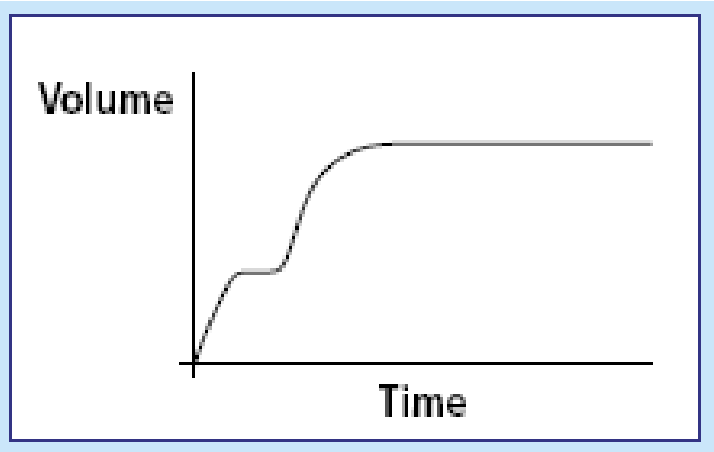
Coughing during exhalation

- Abrupt stop in exhalation
- Short intake of air (start of cough)
- Irregular patter of exhalation



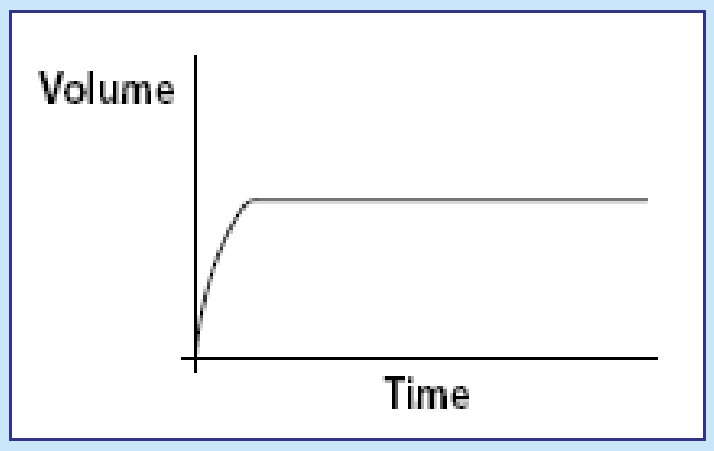
Slow start to forced exhalation

- Marked increase in force of exhalation short time after start of manoeuvre (steep change in gradient on trace)



Extra breath taken during manoeuvre

- Extra breath shown by abrupt short plateau before total expiratory volume reached
- Following extra breath, total volume of air expelled > would have been with only original exhalation



Early stoppage of manoeuvre

- Normal start to manoeuvre
- Reaches plateau abruptly

Confirming COPD diagnosis via spirometry

- FEV_1 <80% predicted AND
- FEV_1/FVC <0.7 (70%)
- Asthma can show same abnormalities → reversibility testing
- Spirometry - poor predictor of disability/QOL

Severity of airflow obstruction

- NICE COPD guideline definitions:

- Mild → FEV_1 50-80% predicted
- Moderate → FEV_1 30-49%
- Severe → FEV_1 <30%

- Rx decisions based on severity

Consider COPD diagnosis in....

- Smokers/ex-smokers > 35yrs
- Exposure to respiratory irritants
- Chronic SOB, cough, sputum, recurrent chest infections, wheeze

COPD or asthma?

- Slow, progressive symptoms → COPD
- Symptoms pre-35 years → asthma
- Serial peak flow monitoring
- NICE - bronchodilator reversibility testing not routinely used where clinical features/spirometry indicate COPD

COPD or asthma?

	COPD	Asthma
Smoker or ex-smoker	Nearly all	Possibly
Symptoms under age 35 years	Rare	Often
Chronic productive cough	Common	Uncommon
Breathlessness	Persistent and progressive	Variable
Night time waking with breathlessness and/or wheeze	Uncommon	Common
Significant diurnal or day to day variability of symptoms	Uncommon	Common

Reversibility testing

Bronchodilator	Asthma	FEV_1 before and after
salbutamol	2.5–5mg (nebuliser) 200–400mcg (large volume spacer)	20 minutes
terbutaline	5–10mg (nebuliser) 500mcg (large volume spacer)	20 minutes
ipratropium bromide	500mcg (nebuliser) 160mcg (large volume spacer)	45 minutes

- Asthma indicated → large response to bronchodilator or 2/52 trial of 30mg Prednisilone daily (> 400ml)

or

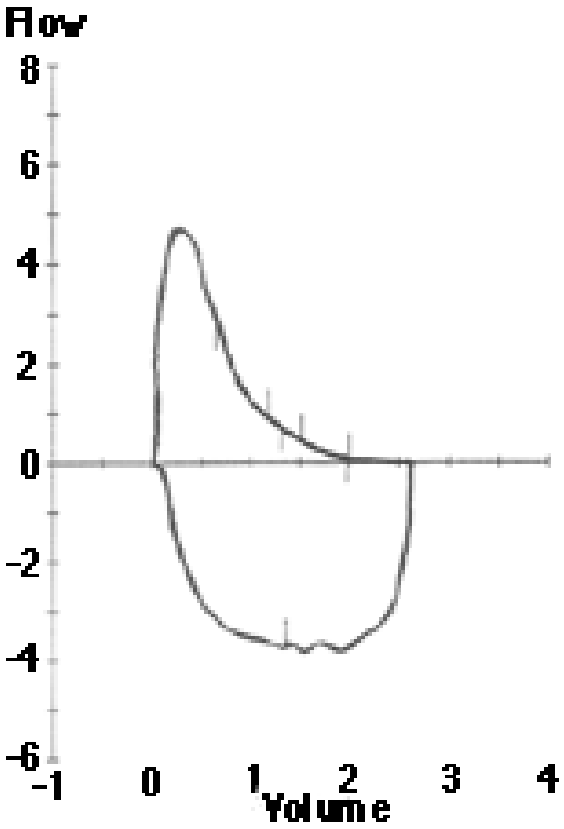
- Spirometry/clinical response 1/12 bronchodilator therapy

- RT - not 'gold standard' → interpret results with clinical Hx

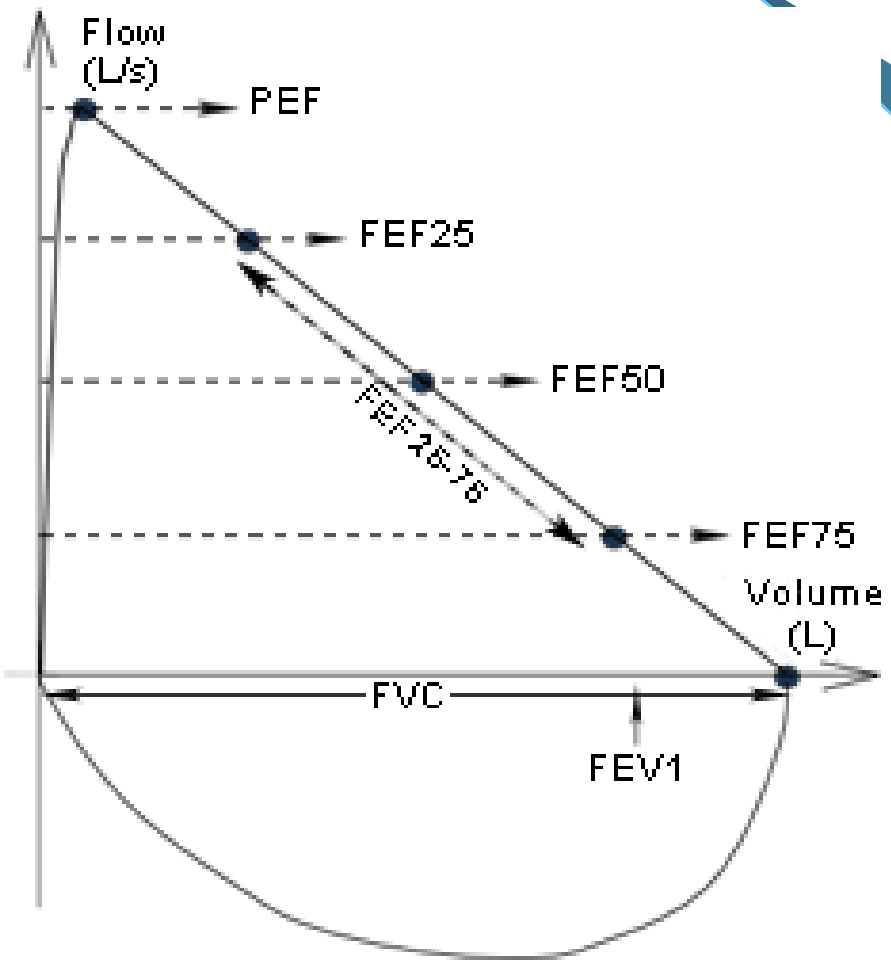
Flow-volume measurement

- Basic spirometry → volume-time curve
- Flow-volume curve → expiratory flow rate plotted against the volume of air exhaled
- Overall shape of flow-volume curve → detects airflow obstruction at an early stage/provides additional information

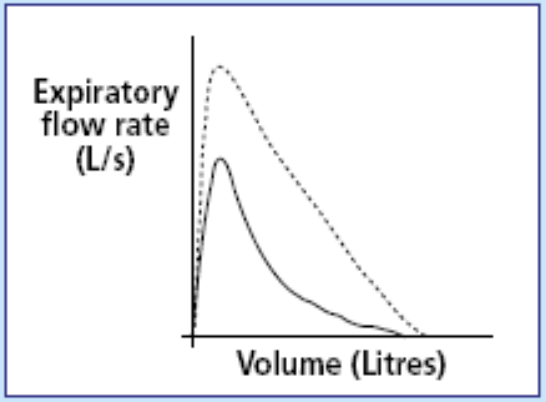
Flow-volume loop



PEF, FEF

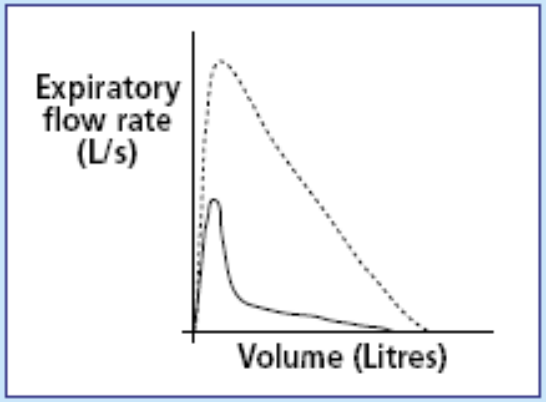


Identifying abnormalities



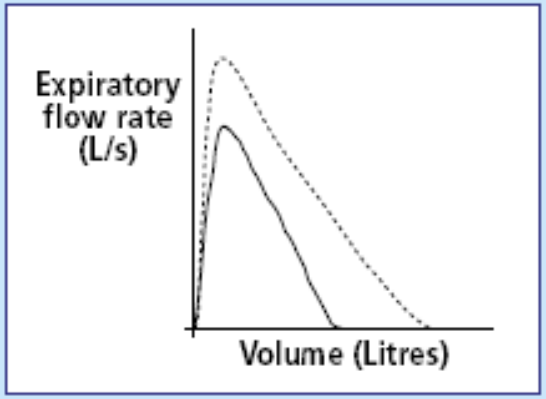
Obstructive disorder

- Peak expiratory flow (PEF) is reduced
- decline in airflow to complete exhalation follows a distinctive concave curve



Severe obstructive disorder

- In severe airflow obstruction → characteristic 'steeple pattern' in expiratory flow trace

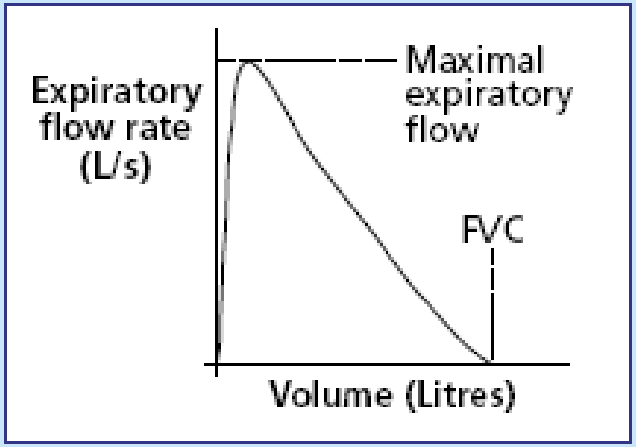


Restrictive disorder

- Pattern in expiratory trace normal in shape but absolute reduction in volume

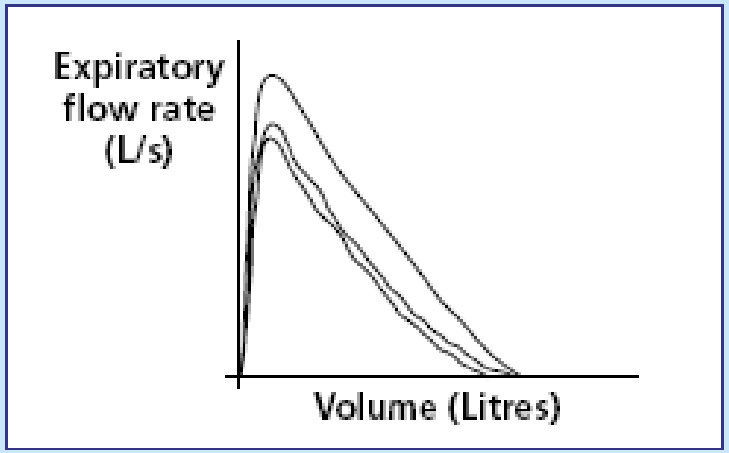
Normal flow-volume curves

On exhalation, there is a rapid rise to the maximal expiratory flow followed by a steady, uniform decline until all the air is exhaled.

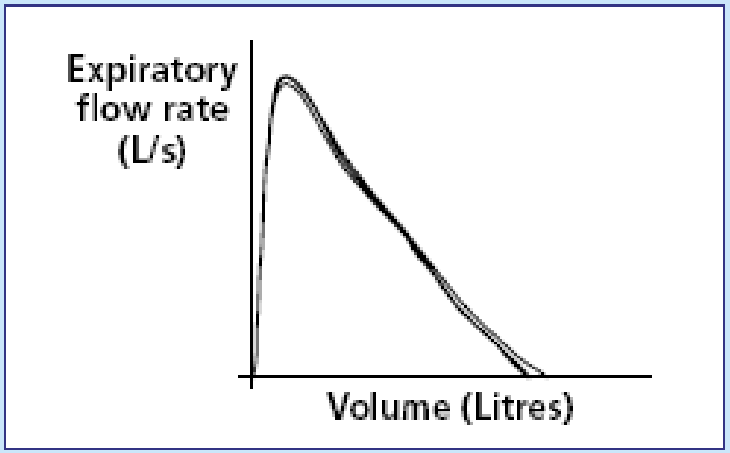


Inconsistent and consistent flow-volume curves

As with volume-time curves, three consistent flow-volume curves are required.



Inconsistent: Although each trace is technically acceptable, they are inconsistent.



Consistent: Three acceptable and consistent traces.

Spirometry in practice

Case Studies

MARION , COOK, AGED 55 YEARS

- Smoker since mid 20's (30/day)
- Not as fit as she used to be. Jokes about "*old age creeping on*" and uses that excuse to avoid anything too strenuous
- Paces herself at work/delegating heavier jobs to younger colleague
- ↑ dyspnoea → difficulty keeping up with the family during walking
- no evidence of heart disease
- Only symptom → "smoker's cough"
- On basis of history → provisional clinical diagnosis of COPD

Examination

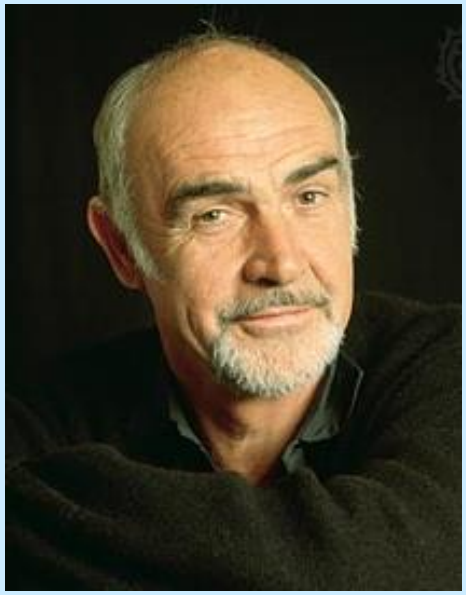
Spirometry	Interpretation
FEV_1 = 1.39 (56% predicted)	Reduced
FVC = 2.53 (86% predicted)	Normal
FEV_1/FVC ratio = 0.55	Reduced

Conclusion

- Mild obstruction → firm diagnosis of COPD
- Marion unaware that smoking caused COPD
- Smoking cessation
- Bronchodilator inhaler (β2-agonist or antimuscarinic) → improve exercise tolerance

RONALD, RETIRED BRICKLAYER, AGED 69 YEARS

- Bad chest for years
- Started smoking in army. Cigarettes cheap, socially acceptable & "good for you"
- After leaving army, smoked up to 40 cigarettes/day
- Retired 15 years ago on health grounds (SOBOE bricklaying)
- Productive cough and for some years/courses ABx for winter chest infections
- Unable to cope with working gardening/DIY
- Wife now complains → always "under her feet"
- Cyanosed



Examination

Spirometry	Interpretation
FEV_1 = 0.89 (28% predicted)	Reduced
FVC = 2.74 (67% predicted)	Reduced
FEV_1/FVC ratio = 0.32	Severe obstruction

Conclusion

- Severe COPD (FEV_1 <30%)
- Bronchodilator therapy stepped-up
- Symptomatic benefit → combination of beta-agonists & antimuscarinics
- SPO_2 89% on air
- ABG → chronic hypoxia (LTOT)
- Started on long acting bronchodilator (beta agonist or antimuscarinic)
- Due to FEV_1 <50% predicted/frequent exacerbations → started on inhaled steroid

JOHN, AN AREA SALES MANAGER, AGED 42 YEARS

- Always been "chesty"
- As a child considered "wheezy"/avoided PE
- Started smoking early 20's (10 cigarettes/day since)
- Generally enjoyed good health/occasional URTI
  → coughing/wheeze
- Prescribed ABX to treat "bronchitis" → slow recovery (blamed smoking)
- Consulted his GP → another cold had "gone to his chest"
- Sleep disturbed by cough/wheeze
- Unclear on basis of history → asthma or COPD or both

Examination

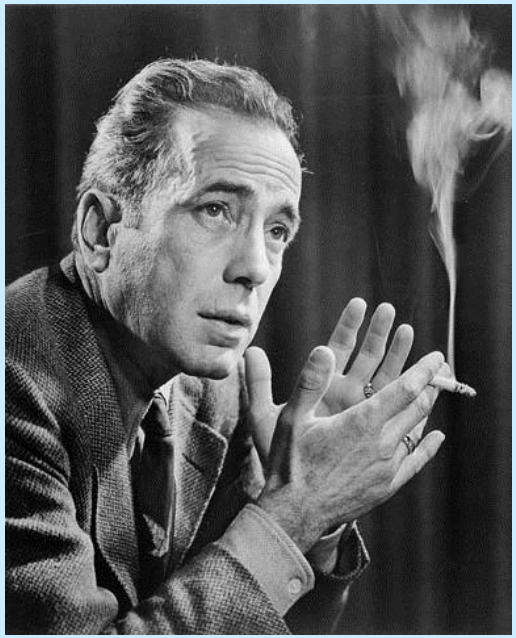
- Bronchodilator response tested (4 puffs salbutamol)
- FEV_1 re-measured after 30 minutes

Spirometry		Interpretation
Baseline	FEV_1 = 3.24 (76% predicted)	Slightly reduced
	FVC = 4.82 (91% predicted)	Normal
	FEV_1/FVC ratio = 0.67	Slightly reduced
Post-bronchodilator	FEV_1 = 4.17 (+ 930 ml and 29%)	Significant reversibility

CONCLUSION

- Mild degree of obstruction → highly responsive (significant reversibility) to bronchodilator
- Significant reversibility/clinical history are highly indicative → asthma
- Advised on long-term impact of smoking/risk of developing COPD
- Smoking cessation

EDDIE, A RETIRED PAINTER AND DECORATOR, AGED 65 YEARS



- Only recently complaining of cough/SOB
- Started smoking as young man
- Feels may have developed asthma
  - lives close to main road (affects of pollution)
  - 2 nephews recently diagnosed with asthma
- Otherwise fit and well/takes no medication
- Few fine crackles on auscultation
- Although asthma suspected → peak flow chart steady at 350 L/minute

Examination

Spirometry	Interpretation
FEV_1 = 1.67 (57% predicted)	Reduced
FVC = 2.07 (55% predicted)	Reduced
FEV_1/FVC ratio = 0.81	Normal

Conclusion

- Abnormal FEV_1 and FVC readings (both well below 80% of the predicted normal values)
- However the FEV_1/FVC ratio >70% → restrictive disease
- Fibrosing alveolitis diagnosed
- Condition unrelated to environmental air pollution

Surgical risk levels

Risks	± Low risk	++ Risky	+++ V HIGH risk
ppoFEV$_1$ %	> 40%	30-40%	**< 30%**
ppoDLCO %	> 40%	30-40%	**< 30%**
VO2 (ml/kg/min)	> 15ml/kg/min	10-15ml/kg/min	**< 10 ml/kg/min**
Stair climb (flight)	> 3	2-3	**< 2**
6-m walk (feet)	>2000	1-2000	**< 1000**

Cahalin L, *Chest* 1995; **108:** 452-57 Rao V, *Ann Thorac Surg* 1995; **60:** 603-9
Ninan M, *Ann Thorac Surg* 1997; **64:** 328-33

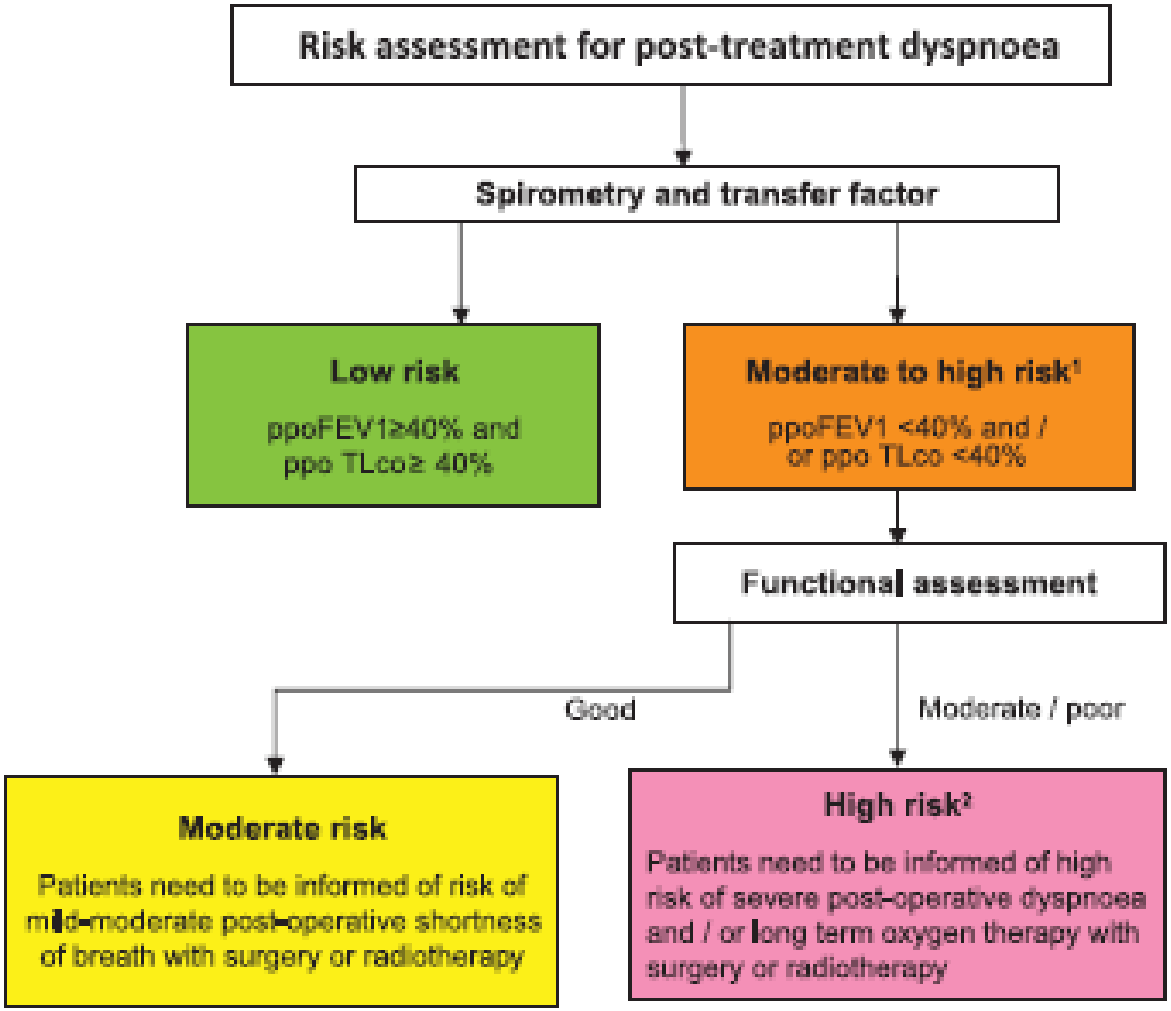
thorax.bmj.com

BMJ|Journals

Supplement

Guidelines on the radical management of patients with lung cancer

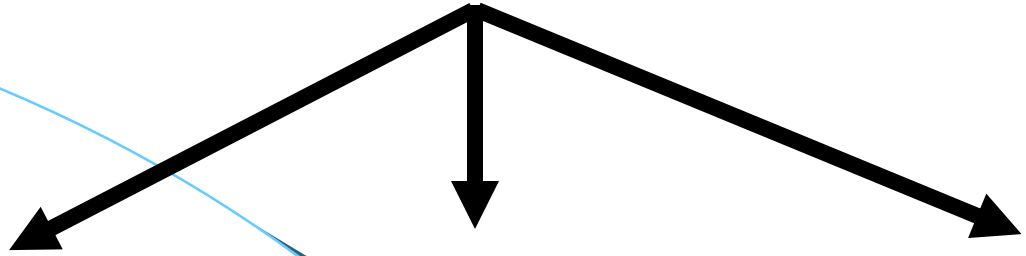
Eric Lim,[1] David Baldwin,[2] Michael Beckles,[3] John Duffy,[2] James Entwisle,[4] Corinne Faivre-Finn,[5] Keith Kerr,[6] Alistair Macfie,[7] Jim McGuigan,[8] Simon Padley,[9] Sanjay Popat,[10] Nicholas Screaton,[11] Michael Snee,[12] David Waller,[13] Chris Warburton,[14] Thida Win,[15] British Thoracic Society and the Society for Cardiothoracic Surgery in Great Britain and Ireland



1. Consider split lung function testing for patients in this group if there is any suspicion of a ventilation perfusion mismatch (e.g. compression of a pulmonary artery or marked emphysema in the lobe with cancer) to allow more accurate estimation of post-operative values.

2. Patients in this sub-group are at high risk of ventilator dependency after surgery. It is important to ensure that criteria for LVRS have been considered as lung function can improve in appropriately selected patients.

Preoperative Respiratory Assessment



Respiratory Mechanics

FEV1 (effort/ absolute value)
TLC
RV
FRC

Gas exchange

DLCO

ABG

V/Q Scans

Cardiopulmonary reserve

CPET
Surrogate tests
- Stairs climbing
- Shuttle test
- 6 min Walk

Predicted postoperative FEV1 (ppoFEV1)

$$ppoFEV1 = \text{pre FEV1} \times \frac{(19 - \text{segments to be removed})}{19}$$

obstructed segments

$$ppoFEV1 = \text{pre FEV1} \times \frac{(19 - a) - b)}{(19-a)}$$

a = obstructed segments

b = unobstructed segments to be resected

SEGMENTS		**UPPER**	**3**		**UPPER**	**5**
	RIGHT	**MIDDLE**	**2**	**LEFT**		
		LOWER	**5**		**LOWER**	**4**

V/Q Scans

- Useful in prediction of postoperative function.
- Postoperative FEV1= Preop FEV1 x % radioactivity contributed by the non operated lung
- Better prediction is given by
  - PPO FEV1 = Preoperative FEV1 x % perfusion of the non operated side.

Wernly JA et.al. J.Thorac.cardiovasc.surg.80:535-543,1980