Spirometry

John D. Brannan *PhD*

Scientific Director , Dept Respiratory & Sleep Medicine

JOHN HUNTER HOSPITAL

February 2020

john.brannan@health.nsw.gov.au

NSW GOVERNMENT Health
Hunter New England
Local Health District

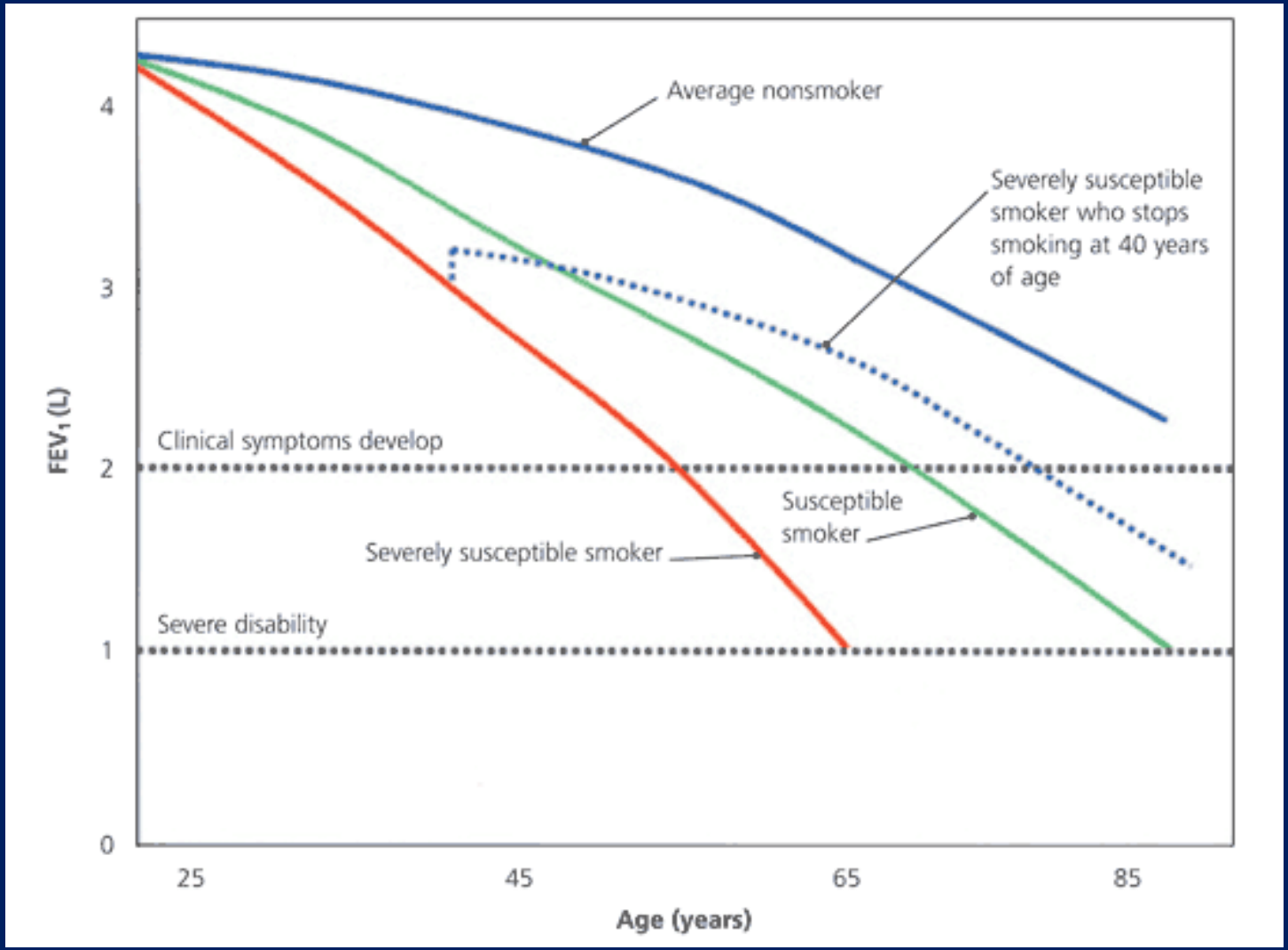
What is spirometry?

- A test of lung function
- Spirometry measures air movement into or out of the lungs:
  - How much (eg FVC or VC) and
  - How quickly (eg FEV_1)
- Measurement is made with a **spirometer**
  - Measures respired volume and flow
- Peak expiratory flow measured by a peak flow meter is no substitute for full spirometry

Why do spirometry?

- In practice
  - Aid to Diagnosis, e.g. asthma, COPD, ILD
  - Monitoring response to treatment
  - Monitoring rate of decline in lung function

Decline in lung function



Other indications

Diagnostic

- To screen individuals at risk of having pulmonary disease
  - eg smokers and ex-smokers, occupational exposure
- To assess preoperative risk
- To assess prognosis in disease
- To assess people wishing to undertake high risk activities (eg scuba diving, vigorous exercise, occupational exposure)
- Central to the assessment of bronchial hyperresponsiveness when performing bronchial provocation tests
  - ?Asthma with normal to near normal lung function
  - Exercise-induced bronchospasm

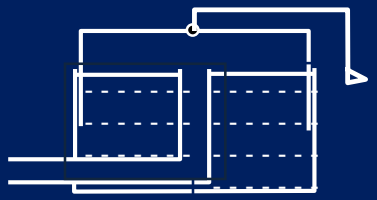
Spirometers

JD.Brannan 2008

Types of spirometer

Volume Spirometers

Rolling Seal

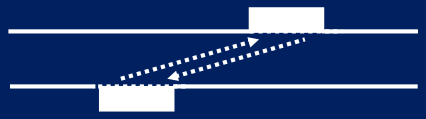


Water Sealed

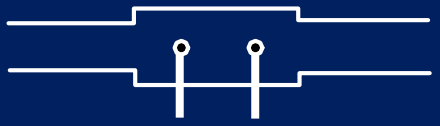
Bellows

Flow Spirometers

Pneumotachographs



Ultrasonic



Hot-wires

Pitot Tube

Turbine

Test requirements

- Test is relatively ‘easy’ to perform but
  - Requires repeated maximal effort and cooperation
  - Involves a vigorous breathing manoeuvre
- Clinically useful results can only be obtained with
  - Reliable and correctly calibrated equipment
  - Experienced and trained personnel

Test requirements

No nose clip may underestimate volume measurements

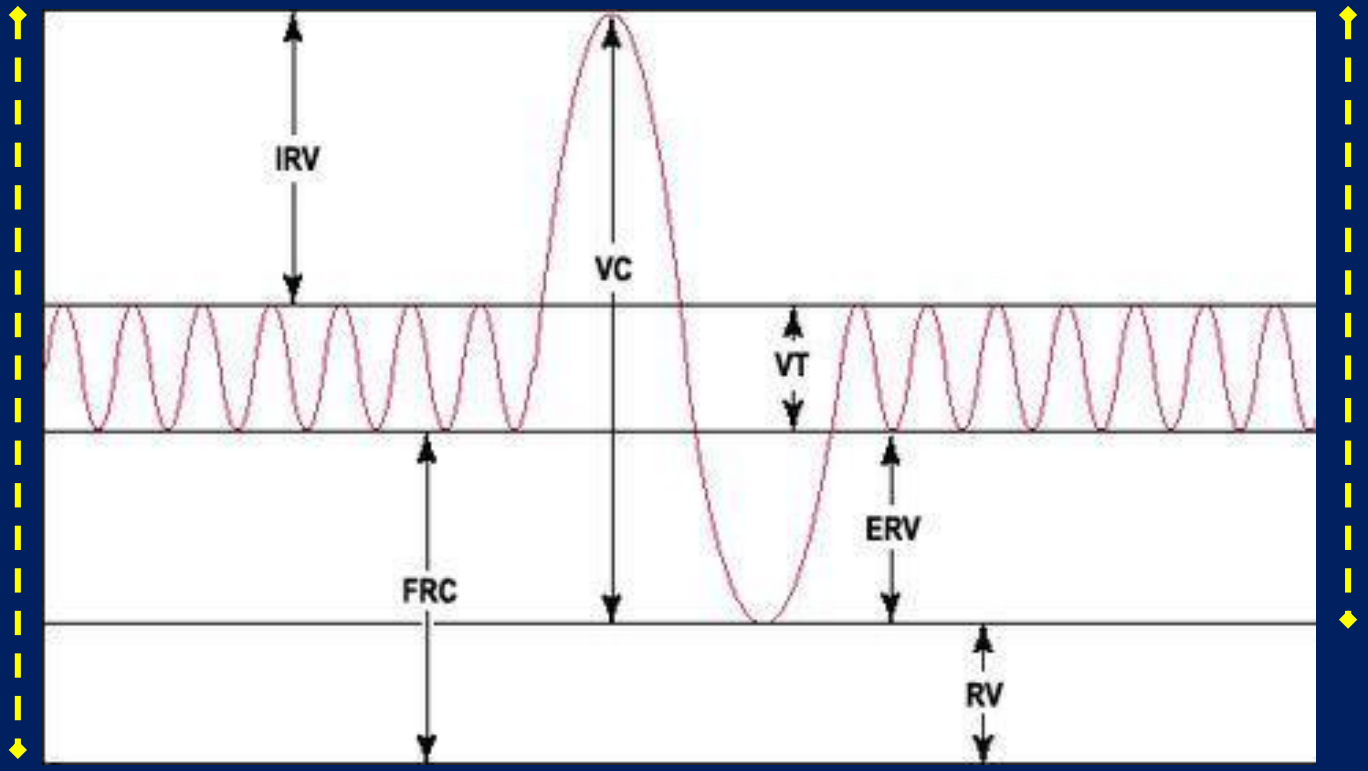
Definitions

- VC (vital capacity):
  - Maximum volume of air that can be expired ‘steadily or smoothly’ following a full inspiration
- FVC (forced vital capacity):
  - Maximum volume of air exhaled with maximally forced effort from a position of maximal inspiration
- RV* (residual volume):
  - Volume remaining in the lungs after maximal exhalation

**Not measured using spirometry*

Lung Volume

Total Lung Capacity



Spirometry

IRV – Inspiratory Reserve Volume
FRC – Functional Residual Capacity
VC – Vital Capacity

VT – Tidal Volume
ERV – Expiratory reserve volume
RV – Residual Volume

Definitions *cont.*

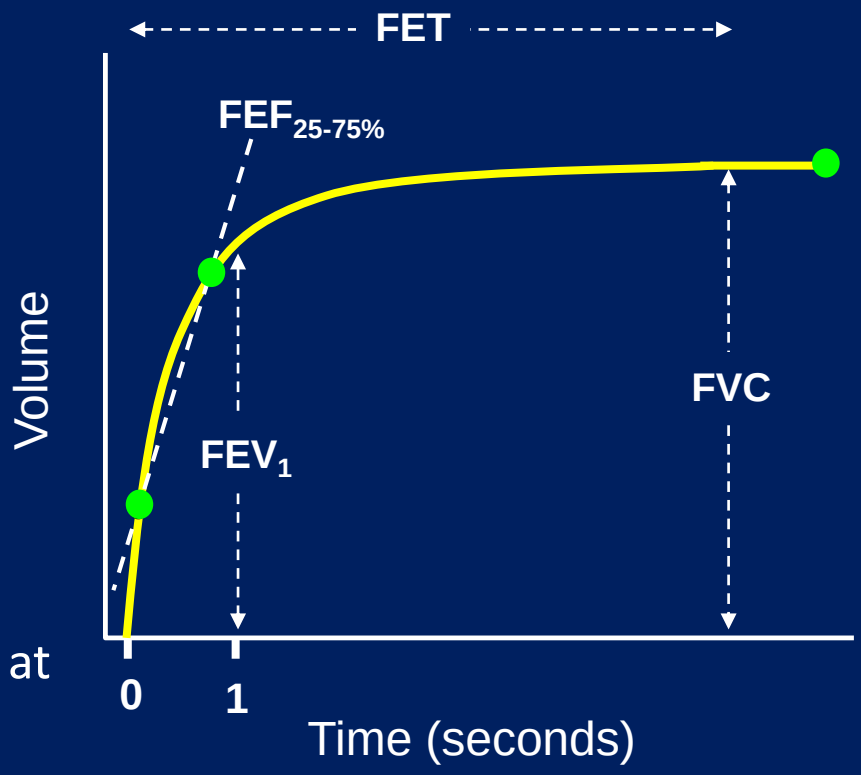
- FEV_1 (forced expired volume in one second):
  - Volume of air that can be forcefully expired in the first second of a maximal FVC manoeuvre
- FEV_1/FVC (or FER, forced expiratory ratio):
  - FEV_1 expressed as a percentage (or fraction) of the FVC
- FEF_{25-75} (forced expiratory flow at 25% to 75% of FVC):
  - Rate of flow through the mid-portion of flow volume curve, may be suggestive of smaller airway function. Can be variable and inaccurate if FVC is under estimated.
- FEV_6 (forced expiratory volume in six seconds):
  - Maximum volume of air that can be expired with maximal effort in 6sec
- PEFR (peak expiratory flow rate):
  - Measure of effort and best PEFR is essential to indicate maximal effort has been performed.

Maximum expiratory flow: PEF

- PEF is **effort** dependent
- Maximum expired flow soon after PEF is reached is **effort independent**
- Maximum expired flow depends on the physical characteristics of the **airways + parenchyma** (and respiratory muscle strength) at time of testing
- *Determinants:*
  - Elastic recoil of lung tissue
  - Resistance of (upstream) airways
  - Respiratory muscle strength
- *Reduced maximum expired flows:*
  - Airway lumen (bronchitis)
  - Airway wall (asthma)
  - Loss of recoil (emphysema)

Volume–time (spirogram)

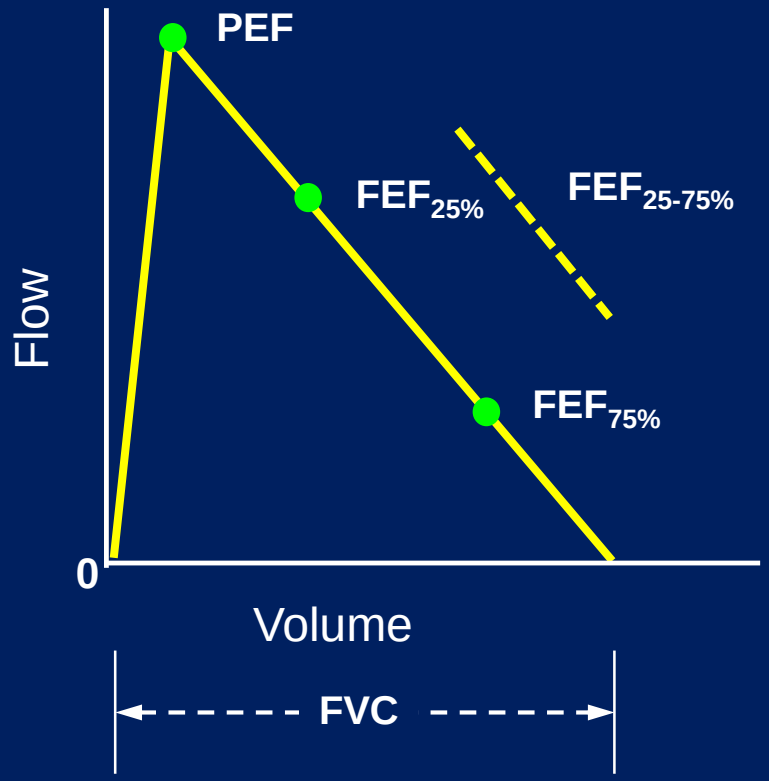
- VC
- FEV_1
- FVC
- FEV_1/FVC (FER)
- $FEF_{25-75\%}$



All volumes and flows reported at
Body **T**emperature and
Pressure **S**aturated (BTPS)

Flow–volume curve

- PEF
- FVC
- FEV_1
- FEV_1/FVC
- FEF_{25-75}
- Shape Analysis



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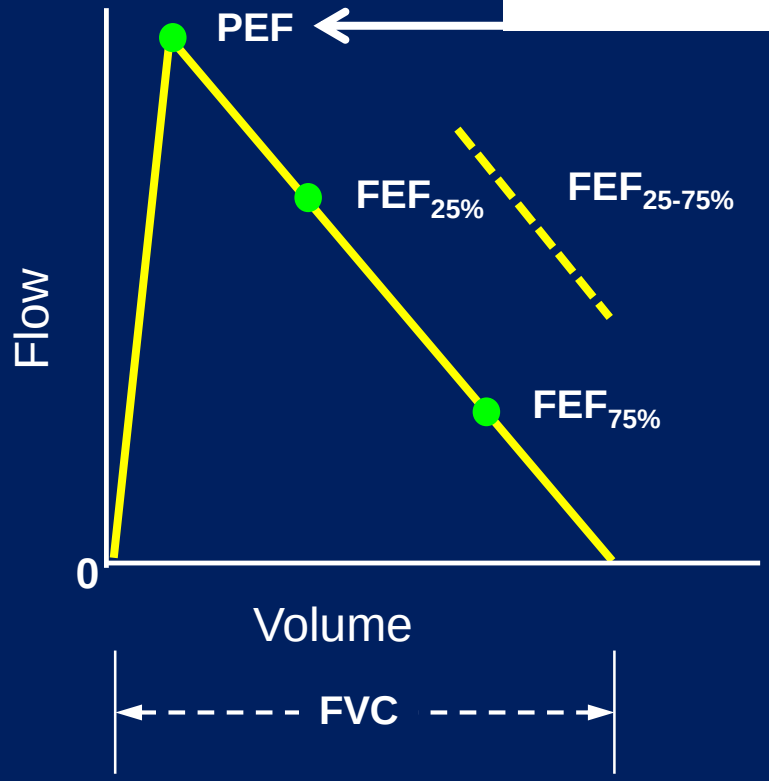

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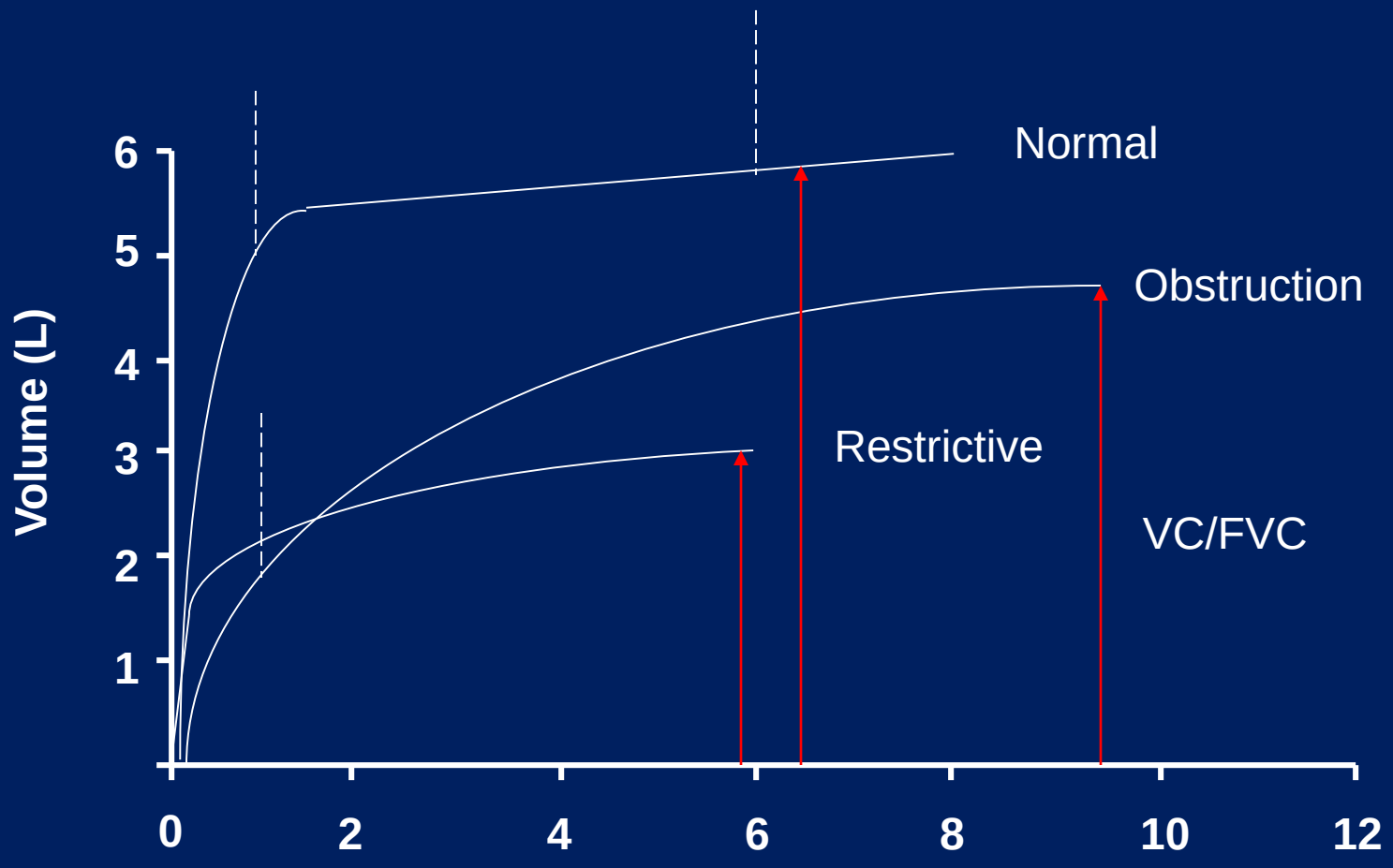
Ventilatory Defects (Volume-Time)



Child/Adolescent ——— <

Adult ——— < >

Obstructive ——— >

Ventilatory defects (Flow-Volume)

Spirometry Performed

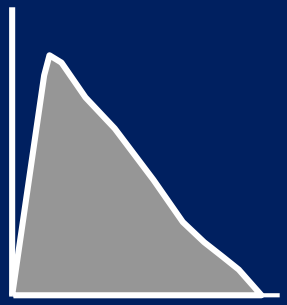
Abnormal Ventilatory Function

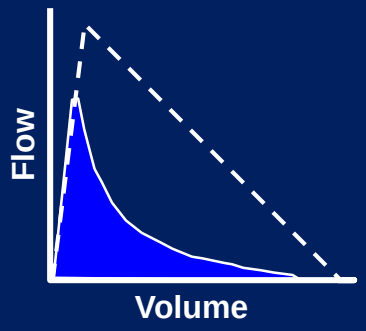
Normal (?)

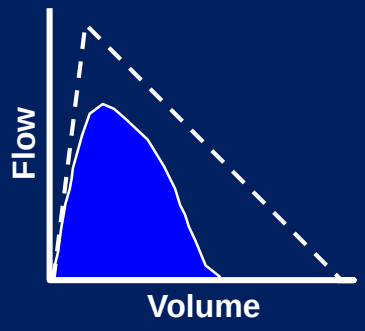
Obstruction

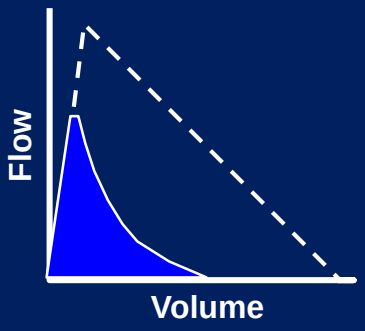
Restriction

Mixed

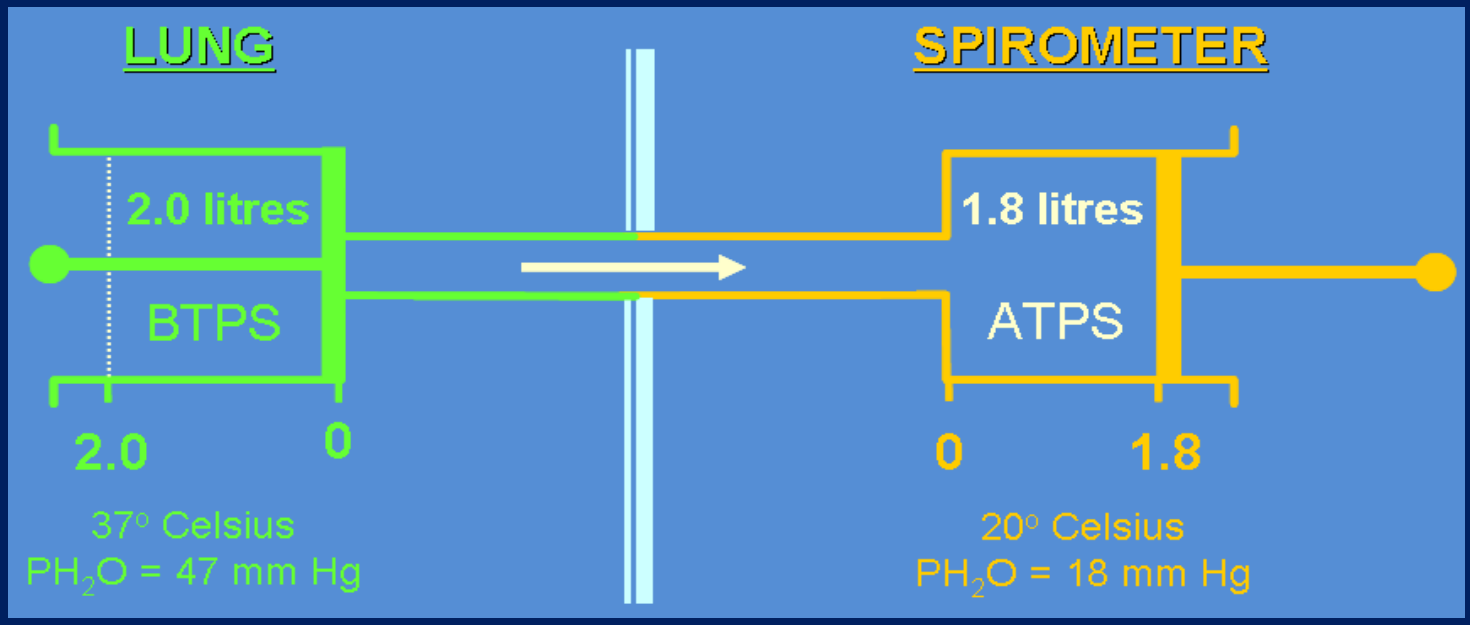






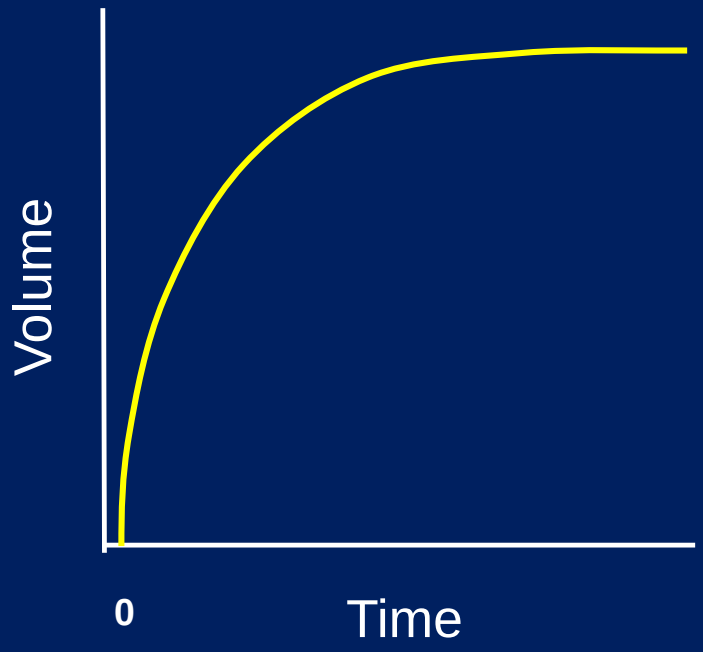


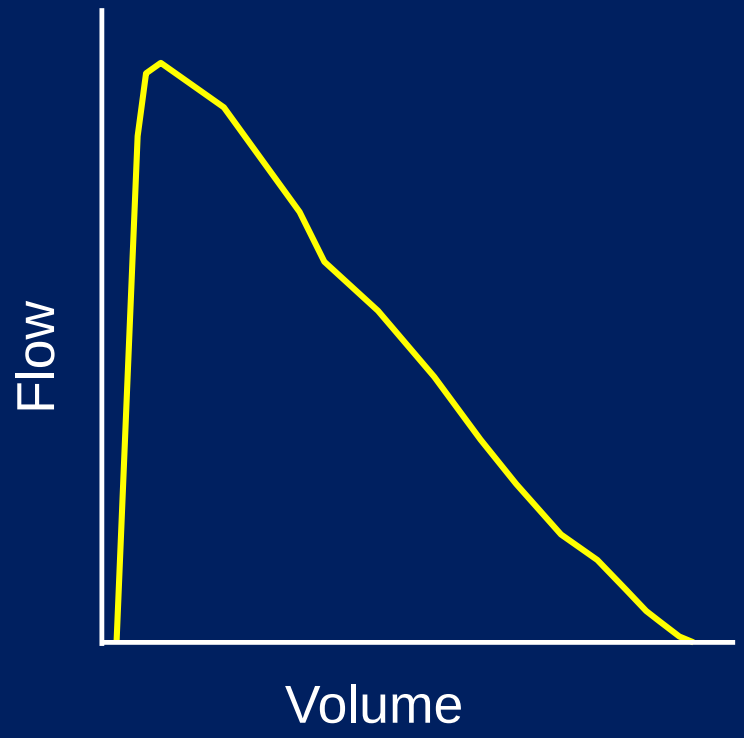
Why report values at BTPS?



- When we blow into a "cold" spirometer, the volume recorded by the spirometer is less than that blown out of the lungs
  - Gas shrinkage (Charles' Law)
  - Condensation of water vapour (vapour pressure falls when gas cools)

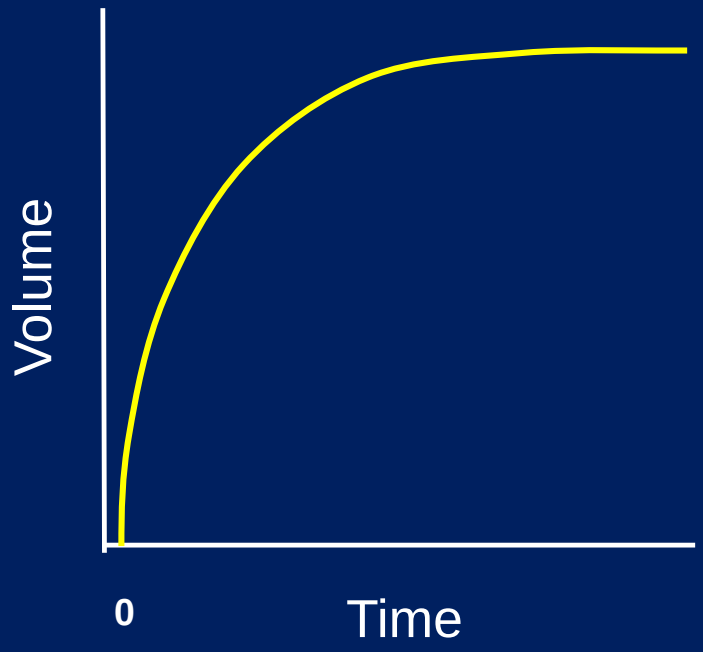
Acceptable spirometry

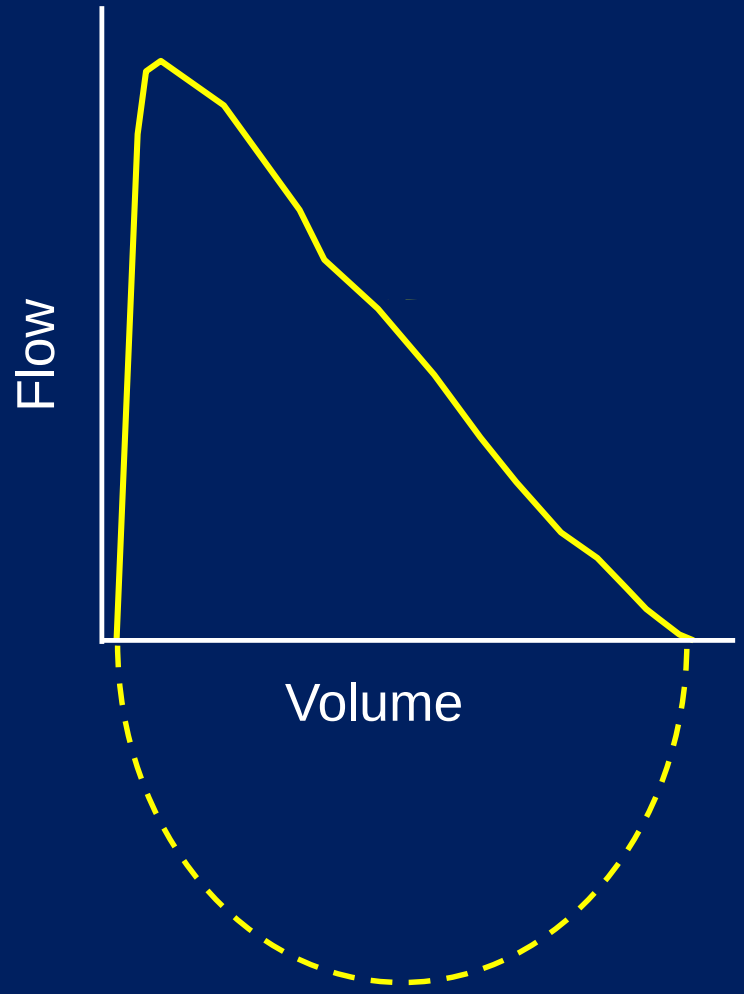




- Good reproducibility
- Rapid start
- Maximum continuous expiratory effort
- At least 6 seconds

Acceptable spirometry





- Good reproducibility
- Rapid start
- Maximum continuous expiratory effort

Pre-test preparation

- Prepare the **spirometer**
- Measure the patient's **weight and height** without shoes
- **Ask** about smoking, recent illness, medication use, etc.
- **Wash hands**
- The test is performed in the **seated and upright** position
  - Patient should maintain the upright posture throughout the test
  - Use of a **nose clip** is recommended
- **Explain** the test in a clear and concise manner
- **Demonstrate** the manoeuvre:
  - This will overcome most patient-related problems

Test performance

- Vigorous verbal **encouragement**/coaching is essential for the patient to continue to exhale to the end of the manoeuvre (eg “keep going”)
- Obtain at least **3 technically acceptable** blows (usually not more than 8 blows are required)
- Check test **repeatability** and perform more blows as necessary
- The FEV1, FVC values should agree to **within 150 mL** of each other or within 5%

Choosing results

- **Largest FEV_1** from acceptable and repeatable manoeuvres (valid FEV_1 can be taken from blows without valid FVC)
- **Largest FVC** from acceptable and repeatable manoeuvres
- **Highest PEF** from any manoeuvre
- **$FEF_{25–75\%}$** from acceptable manoeuvre with highest sum of FEV_1 + FVC
- **Highest FEV_6** from acceptable and repeatable manoeuvres

Poor quality spirometry

Common causes

- Lack of tester knowledge/experience
- Lack of patient understanding/compliance
  - Patient not completely ‘full’ at the start
  - Sluggish initial start to blow
  - Premature termination of blow
  - Tongue occlusion
  - Glottic closure
  - Cough – especially during the first second

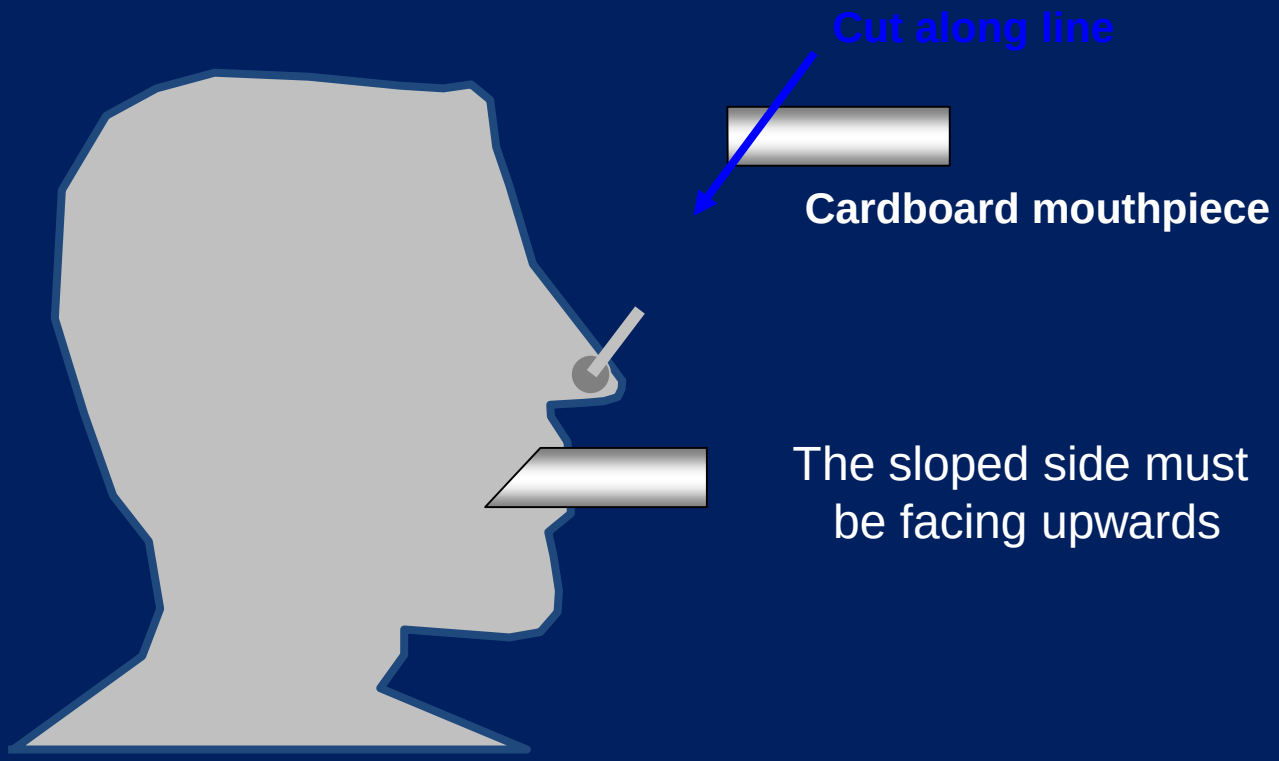
Poor quality spirometry *cont.*

Common causes *cont.*

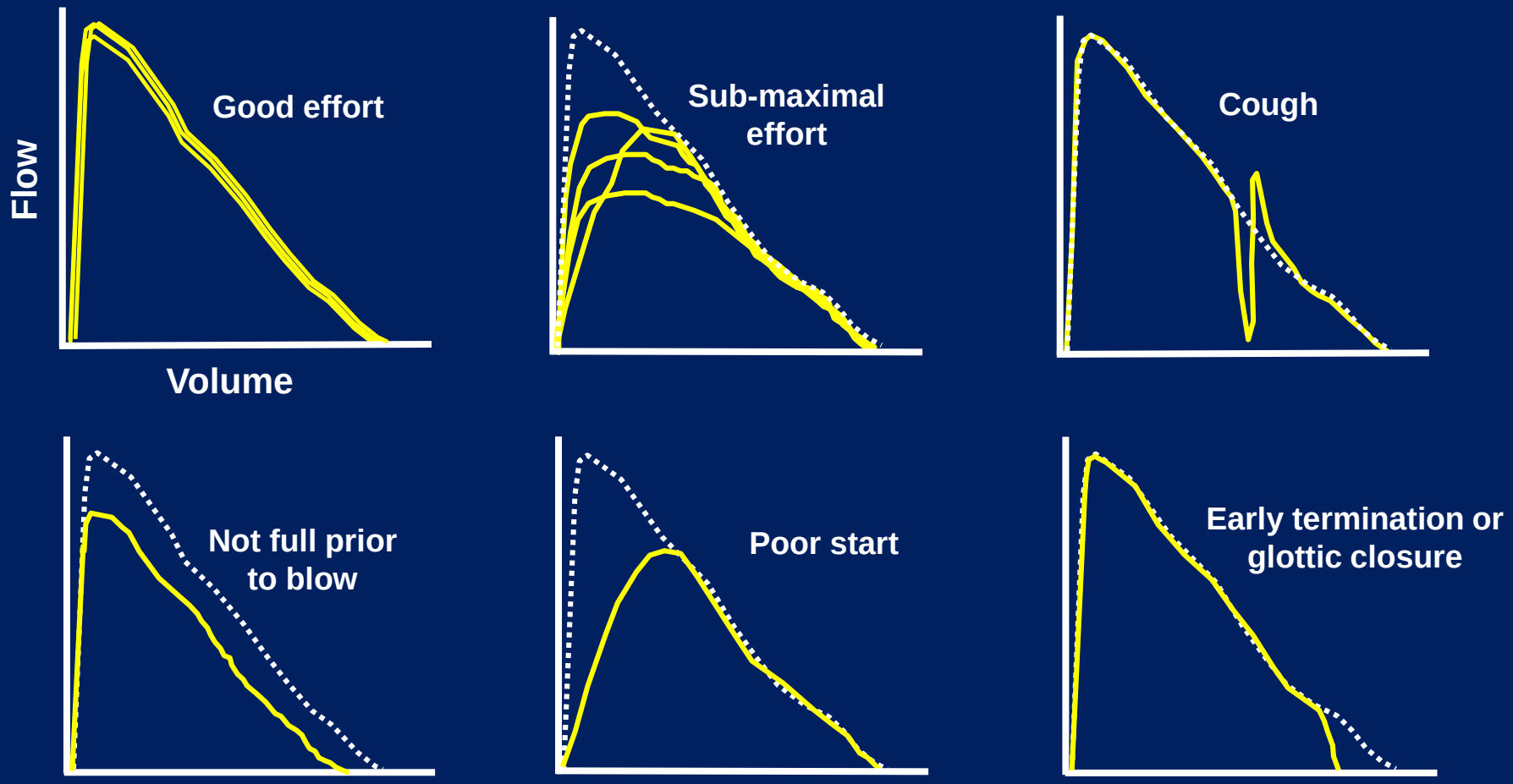
- Lack of knowledge/compliance *cont.*
  - Vocalisation during the blow
  - Poor posture
  - Results not repeatable
  - Leak (eg around mouthpiece)
  - Inaccurate and poorly maintained spirometer
- Inaccurately measured or entered patient details (eg gender, height)

Troubleshooting: patient-related

- Tongue occlusion, eg if cardboard mouthpiece is used
- Some mouthpieces are shaped to minimise tongue occlusion



Troubleshooting: poor flow–volume



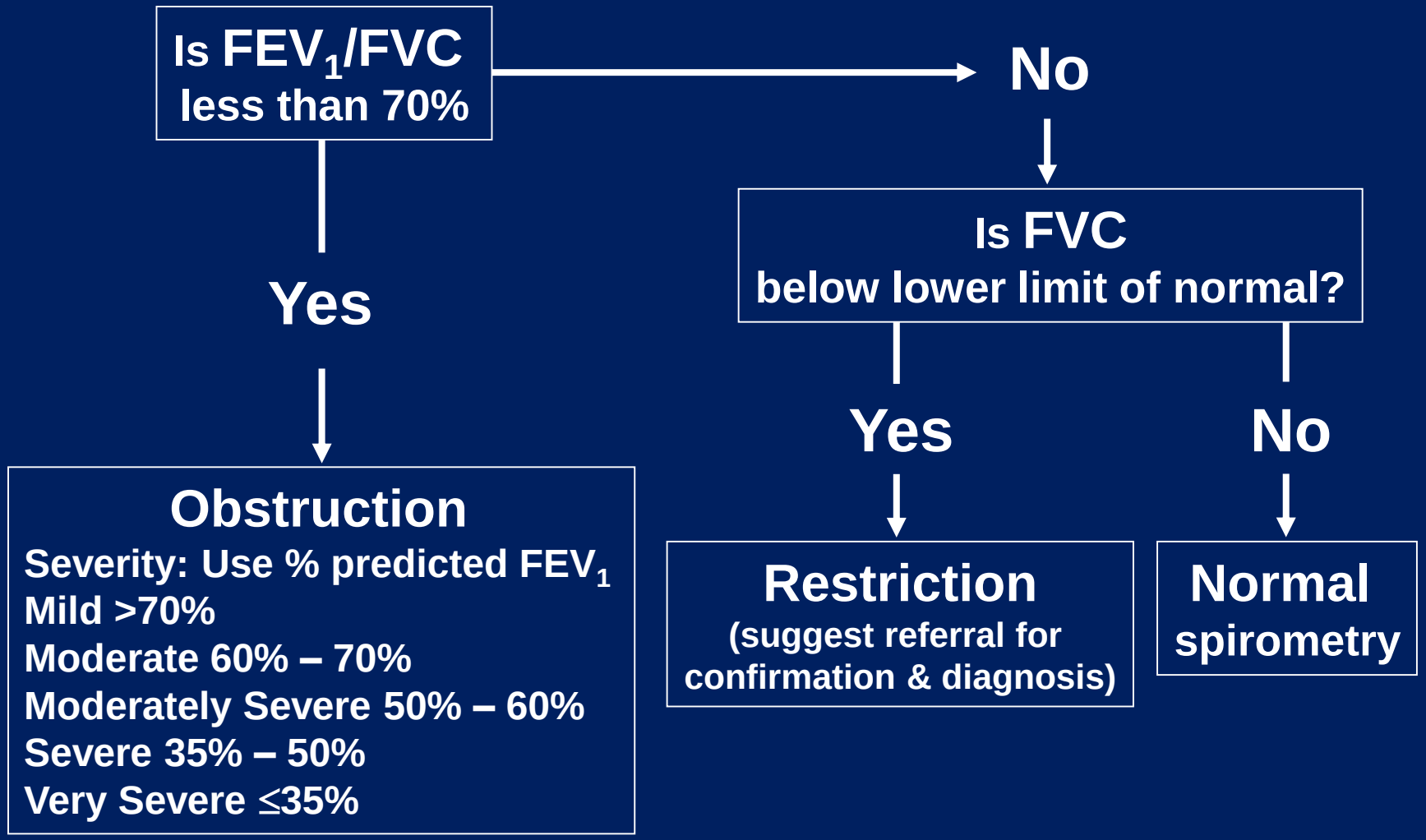
Reference values

- Patient results are compared to reference values
  - Age
  - Height
  - Gender
  - Ethnic origin (?correction factor)
- From tables, regression equations or software:
  - Mean predicted value (80-120% predicted)
  - Standard error of estimate (SEE) = measure of normal variation around the mean predicted value
  - Lower limit of normal (LLN) = Mean – (1.64 x SEE)

Limitations of reference values

- Exercise caution when:
  - Using for patients at extremes of age
  - Using for patients at extremes of height
  - Changing from paediatric to adult reference values
- When spirometry results are available over time
  - Compare findings with patient's previous results over time, not reference values
  - Serial trends provide better indication of change than comparison with reference values

Interpretation algorithm



GOLD criteria for COPD

STAGE	SEVERITY	FEV1 % Pred	FEV1/FVC
Stage 1	Mild	>80	<0.7
Stage 2	Moderate	50-79	<0.7
Stage 3	Severe	30-49	<0.7
Stage 4	Very Severe	<30 <50 + CRF	<0.7

Assessment of reversibility

- Not valid if patient just used bronchodilator (BD)
- Ideally:
  - Short acting β-agonist not used within 6 hrs of test
  - Long acting β-agonists stopped 12 hrs prior to test
  - Ultra-long acting β-agonists stopped 24 hrs prior to test
- To assess bronchodilator reversibility:
  - Perform pre-BD spirometry
  - Administer BD (short acting β-agonist eg salbutamol)
  - Wait 10-15 min
  - Repeat spirometry

Calculation of reversibility

- FEV_1 and FVC are used to quantify reversibility
- Positive BD response is an increase in FEV_1 or FVC of ≥12% **and** ≥200 mL

$$\textit{Absolute change in } FEV_1 = \textit{post-BD } FEV_1 - \textit{baseline } FEV_1$$

$$\textit{\% Improvement in } FEV_1 = 100 \times \frac{FEV_1 \textit{ (post-BD)} - FEV_1 \textit{ (baseline)}}{FEV_1 \textit{ (baseline)}}$$

Medical contraindications

- Haemoptysis of unknown origin
- Pneumothorax in past 6 wks
- Unstable cardiovascular status:
  - Angina, arrhythmia, recent myocardial infarction
- Thoracic, abdominal, cerebral aneurysm
- Eye surgery in past 6 wks
- Acute process that may interfere with test (e.g., nausea, pain)
- Recent thoracic, brain, abdominal surgery
- Severe hypertension
- Active TB
- Angiogram or bronchial biopsy in last 24 hrs
- Intercostal catheter *in situ*

Contraindications

- Recent eye surgery
- Recent thoracic and abdominal surgery
- Aneurysms (eg cerebral, abdominal)
- Unstable cardiac function
- Haemoptysis of unknown cause
- Pneumothorax
- Chest and abdominal pain
- Nausea and diarrhoea

Complications

- Requires maximal effort which may result in:
  - Transient breathlessness
  - Oxygen desaturation
  - Syncope
  - Chest pain
  - Cough
  - Incontinence
- In patients with poorly controlled asthma:
  - Forced manoeuvre can also induce bronchospasm
  - Progressive decrease in FEV_1 with successive blows

Why do spirometry?

- In practice
  - Aid to Diagnosis, e.g. asthma, COPD, ILD
    - *Most asthmatics can have normal spirometry*
  - Monitoring (response to treatment)
    - *Limitation in asthma if lung function normal*
    - *Most of the improvement in FEV_1 with inhaled corticosteroids will occur rapidly (within days/weeks for mild to moderate asthma)*
  - Monitoring rate of decline in lung function

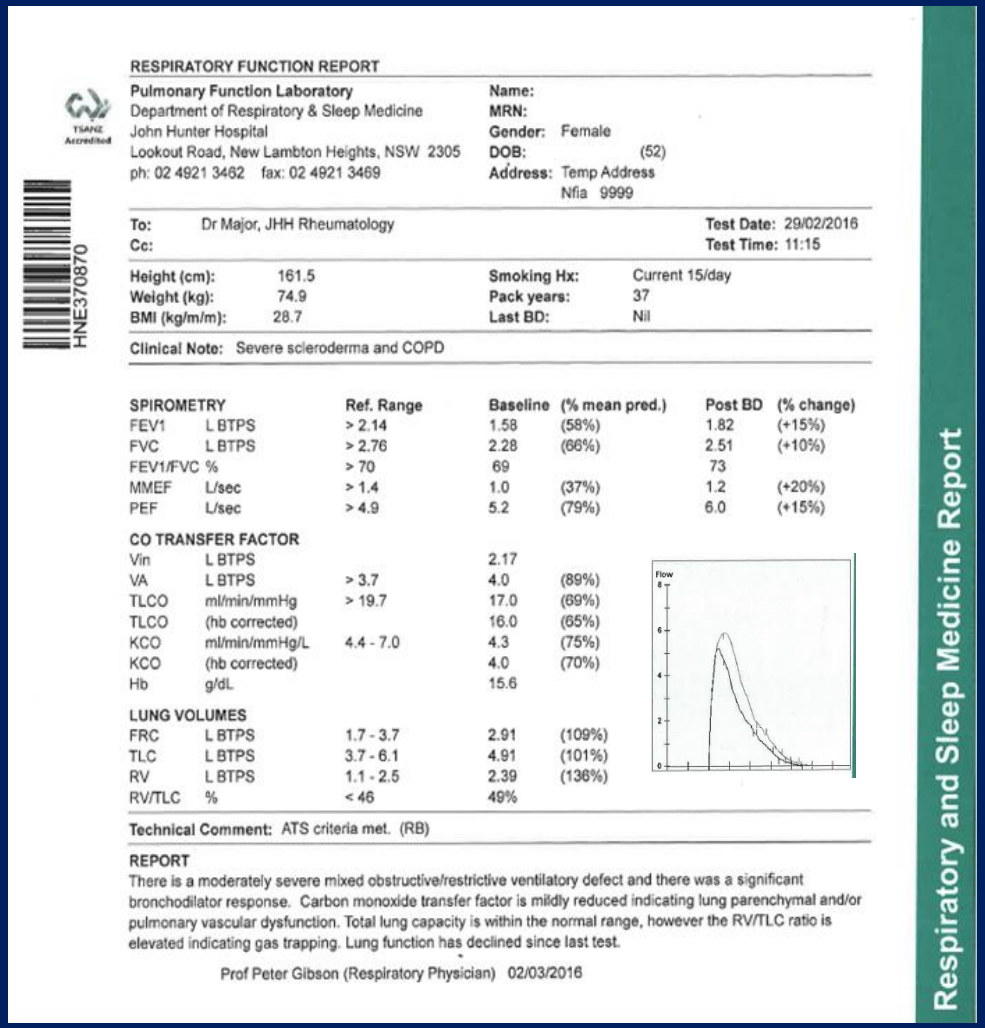
Tests offered in a pulmonary function laboratory that supplement spirometry

Respiratory Function Laboratory
Department of Respiratory & Sleep Medicine
John Hunter Hospital, Lookout Road, New Lambton, NSW 2305
Drs D Arnold, C Grainge, P Gibson, M Hensley, S Pradeepan, S Twaddell, P Wark

Indicate tests required – please circle
(PTO for test information and contraindications)
Tests 1-8 take 15 minutes per test; tests 9-13 take up to 60 minutes per test.

1. Spirometry (Pre/ Post BD) **INSPIRATORY LOOPS required?: Y / N** **(See Note A)**
2. TLCO (Transfer factor, diffusing capacity)
3. Plethysmographic Lung Volumes
4. Exhaled Nitric Oxide (eNO)
5. Maximal Respiratory Pressures
6. 6-Minute Walk Test ☐ On and off O_2 comparison **(see note B)**
7. Arterial Blood Gases
8. Allergen Skin Prick Testing **(see note C)**
9. Hypertonic Saline / Mannitol Challenge **(see notes C and D)**
   Specify if Saline challenge requires INSPIRATORY LOOPS: Y / N
10. Sputum induction (using hypertonic saline)
11. Cardiopulmonary Exercise Test (CPET) **(see note B)**
12. Exercise Provocation Testing **(see notes B, C and D)**
13. Altitude Simulation Testing
14. Overnight Oximetry ☐ Room air ☐ Other_____
15. Other (eg. Forced oscillation technique), Specify:

PFT Lab report: Screening tests



RESPIRATORY FUNCTION REPORT

Pulmonary Function Laboratory
Department of Respiratory & Sleep Medicine
John Hunter Hospital
Lookout Road, New Lambton Heights, NSW 2305
ph: 02 4921 3462 fax: 02 4921 3469

Name:
MRN:
Gender: Female
DOB: (52)
Address: Temp Address
Nfia 9999

HNE370870

To: Dr Major, JHH Rheumatology
Cc:

Test Date: 29/02/2016
Test Time: 11:15

Height (cm):	161.5	Smoking Hx:	Current 15/day
Weight (kg):	74.9	Pack years:	37
BMI (kg/m/m):	28.7	Last BD:	Nil

Clinical Note: Severe scleroderma and COPD

SPIROMETRY		Ref. Range	Baseline	(% mean pred.)	Post BD	(% change)
FEV1	L BTPS	> 2.14	1.58	(58%)	1.82	(+15%)
FVC	L BTPS	> 2.76	2.28	(66%)	2.51	(+10%)
FEV1/FVC	%	> 70	69		73	
MMEF	L/sec	> 1.4	1.0	(37%)	1.2	(+20%)
PEF	L/sec	> 4.9	5.2	(79%)	6.0	(+15%)
CO TRANSFER FACTOR						
Vin	L BTPS		2.17			
VA	L BTPS	> 3.7	4.0	(89%)		
TLCO	ml/min/mmHg	> 19.7	17.0	(69%)		
TLCO	(hb corrected)		16.0	(65%)		
KCO	ml/min/mmHg/L	4.4 - 7.0	4.3	(75%)		
KCO	(hb corrected)		4.0	(70%)		
Hb	g/dL		15.6			
LUNG VOLUMES						
FRC	L BTPS	1.7 - 3.7	2.91	(109%)		
TLC	L BTPS	3.7 - 6.1	4.91	(101%)		
RV	L BTPS	1.1 - 2.5	2.39	(136%)		
RV/TLC	%	< 46	49%			

Technical Comment: ATS criteria met. (RB)

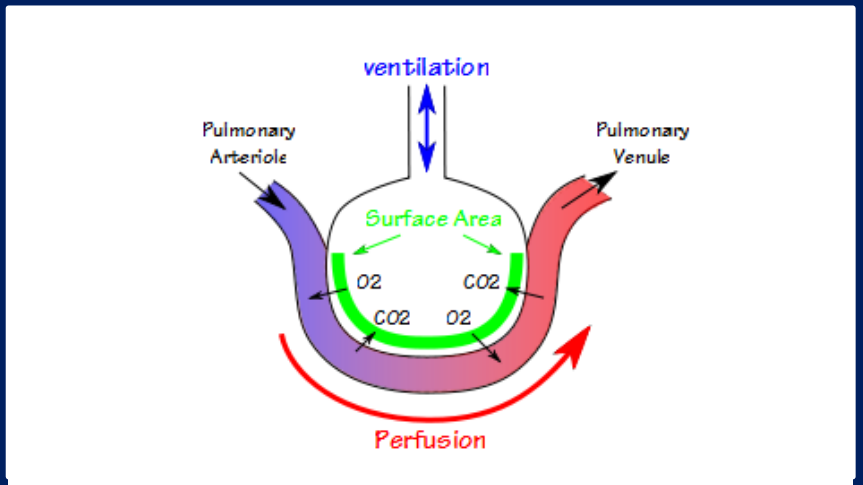
REPORT

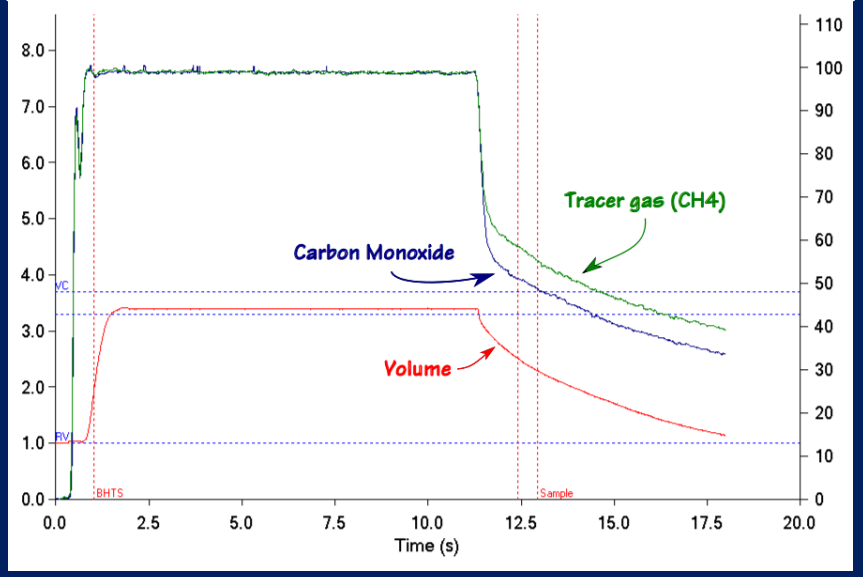
There is a moderately severe mixed obstructive/restrictive ventilatory defect and there was a significant bronchodilator response. Carbon monoxide transfer factor is mildly reduced indicating lung parenchymal and/or pulmonary vascular dysfunction. Total lung capacity is within the normal range, however the RV/TLC ratio is elevated indicating gas trapping. Lung function has declined since last test.

Prof Peter Gibson (Respiratory Physician) 02/03/2016

Respiratory and Sleep Medicine Report

Gas transfer: TLCO or DLCO





TLCO - ml/min/mmHg
KCO - ml/min/mmHg/L
VA - L BTPS
Hb - g/dL (correction)

Involves measuring the partial pressure difference between inspired and expired CO

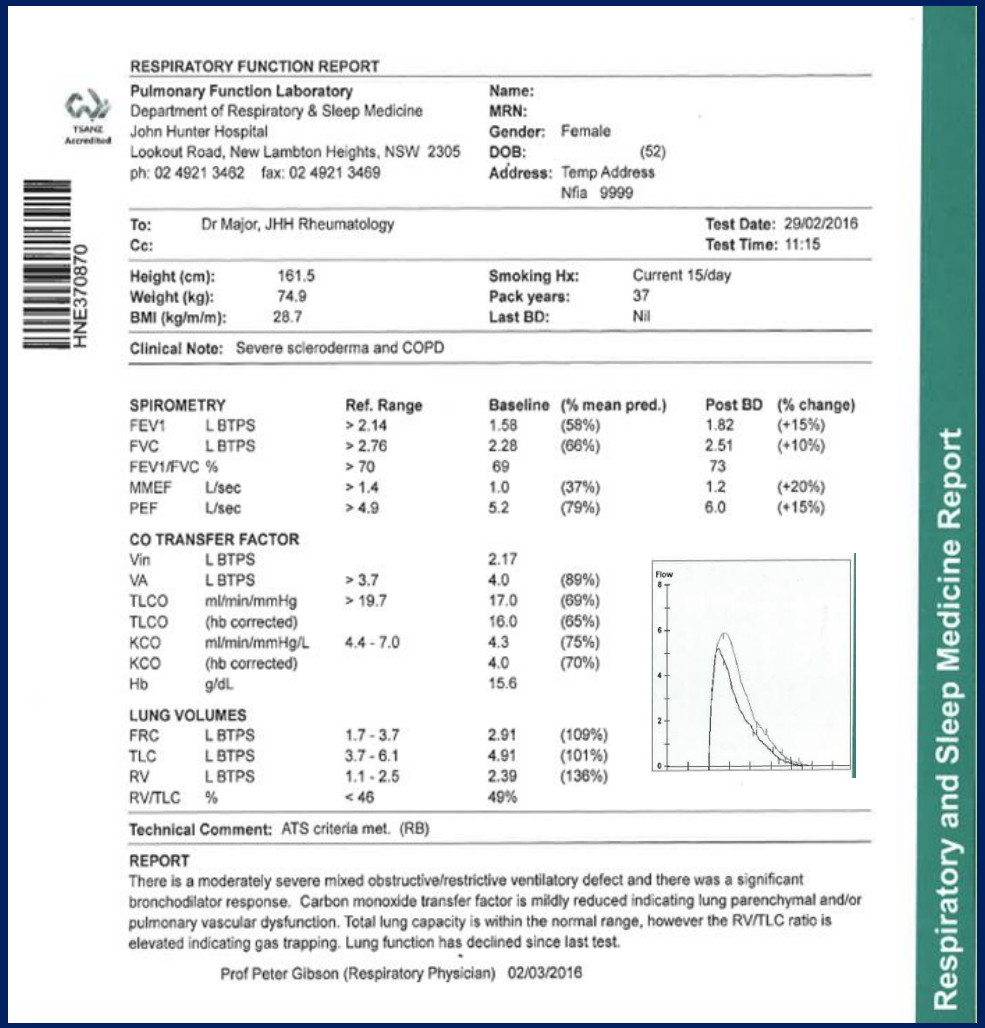
Relies on strong affinity and large absorbtion capacity of red blood cells (Hb) for CO.

Impacted by Hb, COHb, age, gender

Tracer gas permits measurement of alveolar volume. (VA)

Can be corrected for lung volume (KCO)

PFT Lab report: Screening tests



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KCO	(hb corrected)		4.0	(70%)		
Hb	g/dL		15.6			
LUNG VOLUMES						
FRC	L BTPS	1.7 - 3.7	2.91	(109%)		
TLC	L BTPS	3.7 - 6.1	4.91	(101%)		
RV	L BTPS	1.1 - 2.5	2.39	(136%)		
RV/TLC	%	< 46	49%			

Technical Comment: ATS criteria met. (RB)

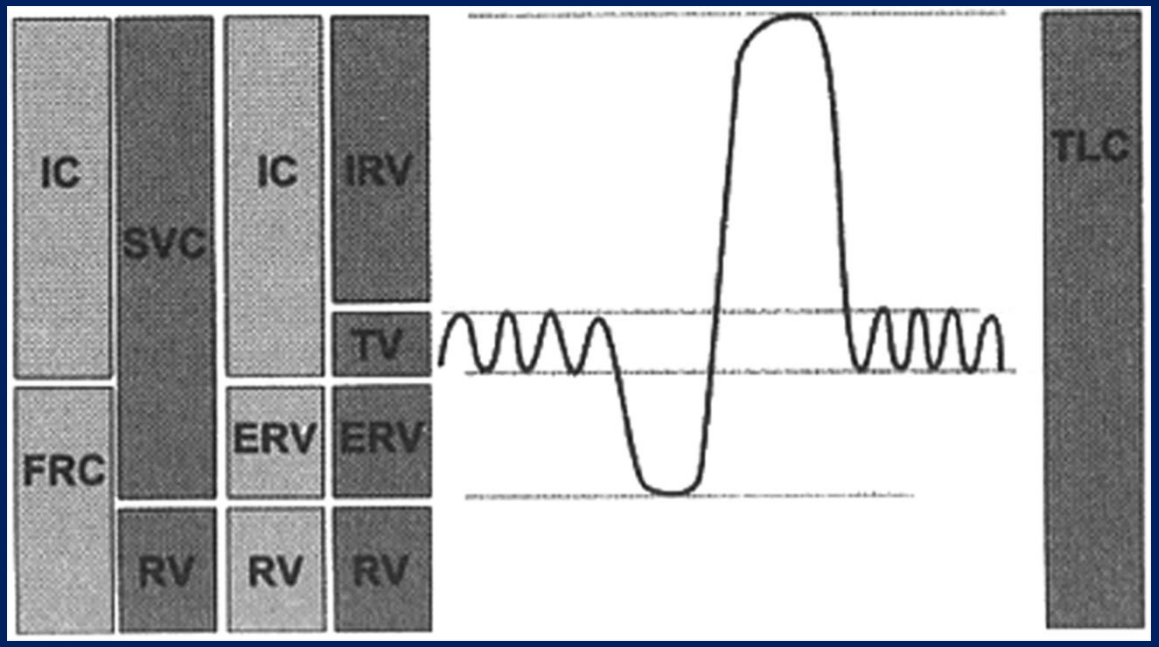
REPORT

There is a moderately severe mixed obstructive/restrictive ventilatory defect and there was a significant bronchodilator response. Carbon monoxide transfer factor is mildly reduced indicating lung parenchymal and/or pulmonary vascular dysfunction. Total lung capacity is within the normal range, however the RV/TLC ratio is elevated indicating gas trapping. Lung function has declined since last test.

Prof Peter Gibson (Respiratory Physician) 02/03/2016

Respiratory and Sleep Medicine Report

Lung volumes



- Static lung volumes are commonly described as <u>volumes</u> (which are not subdivided) or <u>capacities</u> which consist of at least two lung volumes.
- Capacities: TLC, FRC, VC, IC
- Volumes: RV, ERV, Vt, IRV

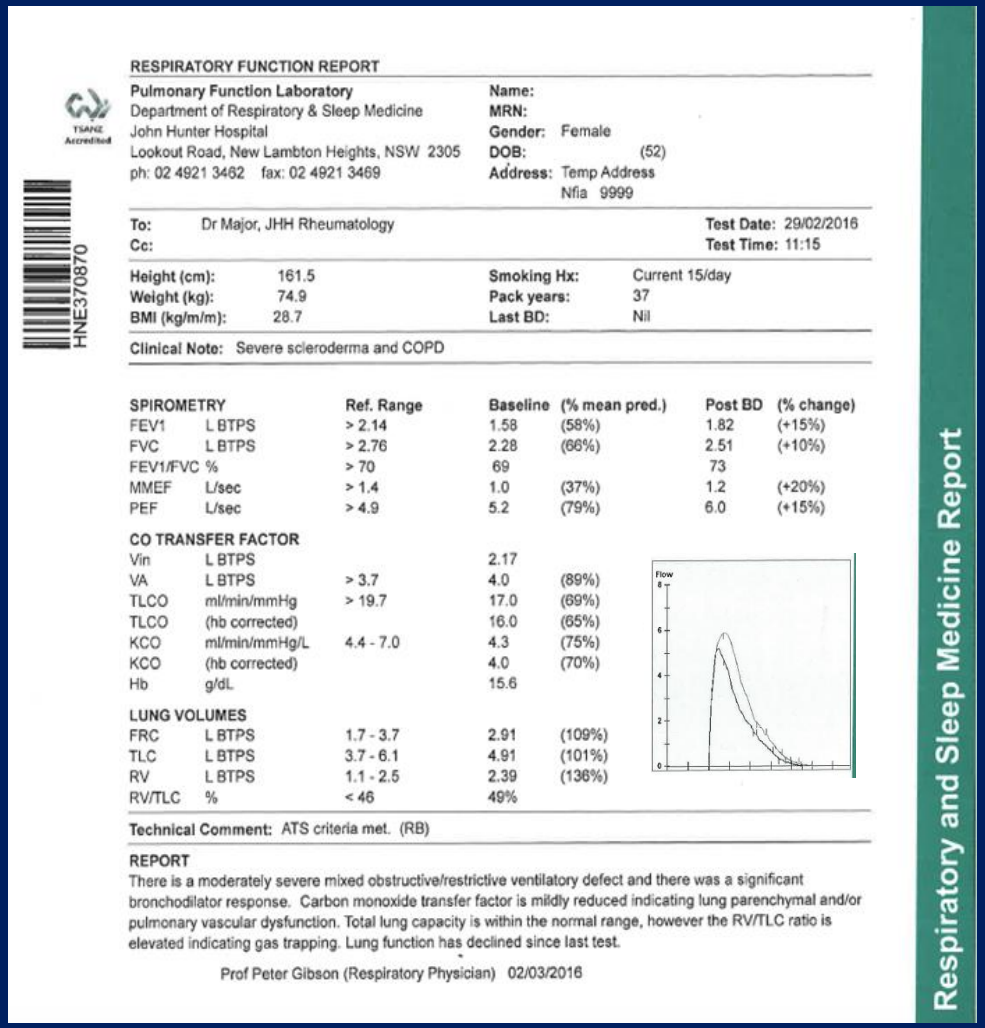
Why measure lung volume?

- Integral part of complete PFTs
- Absolute lung volumes include RV, FRC & TLC
- Spirometry cannot measure RV, FRC & TLC
- Confirming restriction
- Debate: VC comprises most of TLC in normals and restriction

Plethysmography

- The subject is seated in an airtight container or body plethysmography.
- Perform tidal breathing to establish FRC.
- Make gentle panting efforts against a closed shutter (1-2 Hz); mass movement of gas prevented and changes in alveolar volume during the manoeuvre due to compression and decompression of alveolar gas.

PFT Lab report: Screening tests



RESPIRATORY FUNCTION REPORT

Pulmonary Function Laboratory
Department of Respiratory & Sleep Medicine
John Hunter Hospital
Lookout Road, New Lambton Heights, NSW 2305
ph: 02 4921 3462 fax: 02 4921 3469

Name:
MRN:
Gender: Female
DOB: (52)
Address: Temp Address
Nfia 9999

HNE370870

To: Dr Major, JHH Rheumatology
Cc:

Test Date: 29/02/2016
Test Time: 11:15

Height (cm):	161.5	Smoking Hx:	Current 15/day
Weight (kg):	74.9	Pack years:	37
BMI (kg/m/m):	28.7	Last BD:	Nil

Clinical Note: Severe scleroderma and COPD

SPIROMETRY		Ref. Range	Baseline	(% mean pred.)	Post BD	(% change)
FEV1	L BTPS	> 2.14	1.58	(58%)	1.82	(+15%)
FVC	L BTPS	> 2.76	2.28	(66%)	2.51	(+10%)
FEV1/FVC	%	> 70	69		73	
MMEF	L/sec	> 1.4	1.0	(37%)	1.2	(+20%)
PEF	L/sec	> 4.9	5.2	(79%)	6.0	(+15%)
CO TRANSFER FACTOR						
Vin	L BTPS		2.17			
VA	L BTPS	> 3.7	4.0	(89%)		
TLCO	ml/min/mmHg	> 19.7	17.0	(69%)		
TLCO	(hb corrected)		16.0	(65%)		
KCO	ml/min/mmHg/L	4.4 - 7.0	4.3	(75%)		
KCO	(hb corrected)		4.0	(70%)		
Hb	g/dL		15.6			
LUNG VOLUMES						
FRC	L BTPS	1.7 - 3.7	2.91	(109%)		
TLC	L BTPS	3.7 - 6.1	4.91	(101%)		
RV	L BTPS	1.1 - 2.5	2.39	(136%)		
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Prof Peter Gibson (Respiratory Physician) 02/03/2016

Respiratory and Sleep Medicine Report

Thank you, Questions?

What is your lung age?