Spirometry

Key
Major values
- FEV_1 = forced expiratory volume in 1 second
- FEV = forced expiratory volume
- VC = vital capacity
- FVC = forced vital capacity

Special values
- T_LCO (sometimes called D_LCO) = transfer capacity of lung for CO
- KCO = transfer coefficent i.e. diffusing capacity of the lung per unit volume

Other values
- TLC = total lung capacity
- RV = residual volume
- FRV = functional residual volume

Basic spirometry procedure

- **W**ash hands, **I**ntroduce self, **P**atients name & DOB, **E**xplain procedure and get consent
- Obtain patient details: sex, age, height, ethnic origin (to work out predicted value)
- Check that their current condition is stable
- Attach a clean mouthpiece
- Ensure patient is seated and upright, and apply nose clip
- Measure FEV_1 and FVC
    - Tell them to make a deep breath in to full capacity
    - Place their lips around the mouthpiece forming a tight seal
    - Breathe out as hard and fast as possible through their mouth
    - Encourage them to keep exhaling until their lungs feel empty
    - Repeat at least 2 more times
- Measure VC
    - Take a deep breath in to full capacity
    - Breathe out steadily at a comfortable pace
    - Encourage them to keep exhaling until their lungs feel empty
    - Repeat
- Calculate % of predicted values:

$$\%\ \text{predicted} = \frac{\text{Average patient reading}}{\text{Predicated value}} \times 100$$

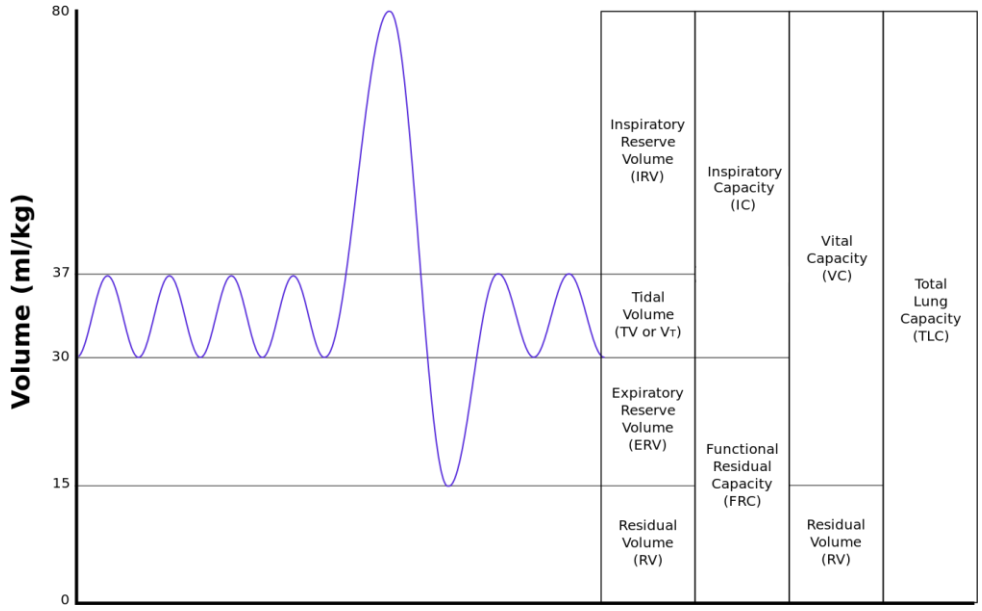
- Calculate the FEV_1/FVC ratio:

$$FEV_1/FVC\ \text{ratio} = \frac{\text{Average } FEV_1 \text{ reading}}{\text{Average FVC reading}}$$

- Thank the patient and document results

Background Physiology

Spirometry graph measurements



Obstructive vs. Restrictive disorders

- **Obstructive disease** such as **asthma, COPD, cystic fibrosis and bronchiectasis** result in obstructed airways creating airway resistance to expiratory flow so the patient will struggle to get air out quickly resulting in a decreased FEV_1. A smaller FEV_1 will therefore also result in a smaller FEV_1/FVC ratio.
  N.B. an obstructive pattern due to Asthma will show reversibility following administration of a bronchodilator such as salbutamol.
- **Restrictive diseases** such **as pulmonary fibrosis/interstitial lung disease, obesity, neuromuscular and chest/spine deformities** restrict lung expansion, reducing the amount of air the lungs can hold (the vital capacity) resulting in a decreased FVC. As there is decreased compliance and elasticity it is also harder for the lungs to force air out quickly resulting in a decreased FEV_1. As both the FEV_1 and the FVC have decreased, the FEV_1/FVC ratio remains near normal.

Basic value interpretation

	Obstructive	Restrictive
FEV_1	**↓** (<80%)	
FVC	**N** (>80%)	**↓** (<80%)
FEV1/FVC ratio	**↓** (<0.7)	**N or ↑** (0.7-0.8) (>0.8)

1. Is the FEV_1 <80% predicted? (lung disease)

- **What:** FEV_1 = volume expelled in the first second of forced expiration (calculated as % of predicted value)
- **Physiology:** FEV_1 is reduced in obstructive disorders because there is airway resistance to expiratory flow, and it is also reduced in restrictive disorders because there is decreased compliance and elasticity so lungs can force air out quickly.
- **Results:**
  - FEV_1 <80% predicted = lung disease
  - FEV_1 >80% predicted = normal = no lung disease (breathlessness due to another cause e.g. PE, vasculitis)
- **Other points:** FEV_1 is also used to grade severity of COPD into mild (50-80%), moderate (30-50%) or severe (<30%). Asthma is not usually diagnosed with spirometry (as tests are often normal when the patient is asymptomatic. However, reversibility of >12% of FEV_1 to a bronchodilator may suggest the diagnosis. Asthma is usually diagnosed clinically or with serial peak flow demonstrating >20% diurnal variation.

2. What is the FVC? (<80% predicted = restrictive)

- **What:** FVC = total volume expelled from maximal inspiration to forced maximal expiration (calculated as % of predicted value).
- **Physiology:** FVC is reduced in restrictive disorders because there is reduced lung expansion, so the volume the lungs can hold is reduced. In obstructive disorders, there is airway resistance to expiratory flow, but a normal volume of air in the lungs – so the FVC is normal.
- **Results:**
  - FVC <80% predicted = restrictive disorder (FVC is normal in obstructive disorders)
- **Other points:** VC = non-forced total volume expelled from maximal inspiration to maximal expiration (calculated as % of predicted value) – the value will be similar to the FVC but FVC is more commonly used. There is no time limit on either.

3. What is the FEV_1/FVC ratio?

- **What:** FEV_1/FVC ratio = proportional volume breathed out in first second compared to the whole breath (normally 0.7-0.8)
- **Physiology:** This is calculated by the FEV_1 value divided by the FVC value. It is low in obstructive disorders because the FEV_1 is low and the FVC is normal (as above). It is normal or high in restrictive disorders because the FEV_1 is low and the FVC is proportionally as low or lower.
- **Results:**
  - FEV_1/FVC ratio <0.7 = obstructive
  - FEV_1/FVC ratio 0.7-0.8 = normal or restrictive
  - FEV_1/FVC ratio >0.8 = restrictive (if FVC more affected than FEV_1)

Advanced value interpretation

T_LCO and KCO

- **What:** T_LCO = total diffusing capacity of lung – this is measured by breathing in a fixed amount of carbon monoxide in a single breath and calculating how much diffuses into the blood by measuring how much is breathed back out; KCO = T_LCO/alveolar volume = diffusing capacity of lung per unit volume (i.e. as above but corrected for lung volume)
- **Results:**
  - T_LCO ↓ = due to either:
    - Pulmonary vascular bed abnormalities (e.g. pulmonary embolism, pulmonary hypertension)
      - KCO is also ↓ (because diffusion per unit alveolar volume is also affected)
    - Alveolar destruction (e.g. interstitial lung disease, emphysema)
      - KCO is also ↓ (because diffusion per unit alveolar volume is also affected)
    - Reduced alveolar volume (e.g. pneumonectomy)
      - KCO is normal (because KCO corrects for alveolar volume)
    - Incomplete alveolar expansion (i.e. restrictive disorders)
      - KCO is normal (because KCO corrects for alveolar volume)
- **Other points:** in the rare occasion both are raised, this suggests intra-alveolar haemorrhage (e.g. Wegeners or Goodpastures).

TLC and RV

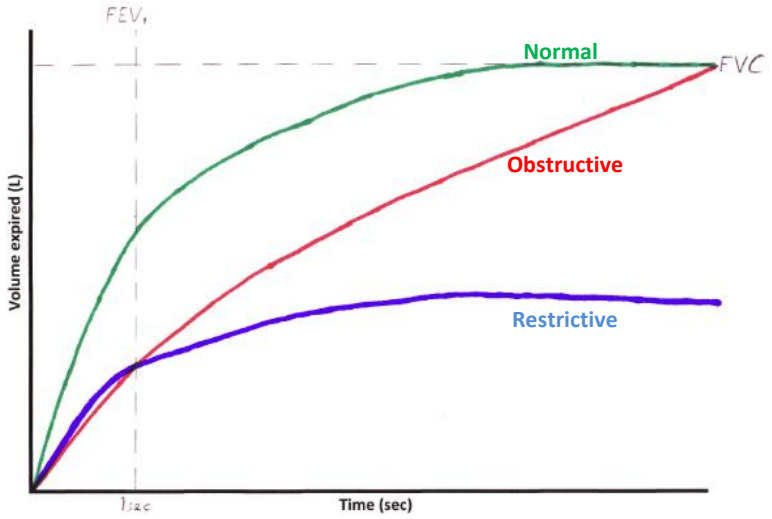
- **What:** TLC = total volume of air inside the lungs – it includes the VC (maximal volume that can be breathed in and out) and the RV (the volume left inside the airways after maximal expiration)
- **Results:**
  - TLC is reduced in restrictive disorders (as described above) and may be high in emphysema due to a high RV caused by reduced elasticity preventing full expiration

Graph interpretation

Volume-time graph

Starting from maximal inspiration, the graph plots the total volume of air expired by time (until full expiration)

- Normal – rapid increase in volume of air expired initially, then plateau
- Obstructive – prolonged increase (because air can't be expired as quickly due to airway resistance) but ends at the same point because the total volume in the lungs is the same
- Restrictive – rapid increase as normal, but reaches plateau much sooner (because total volume of lungs is restricted)



Flow-volume curve

Starting from maximal expiration, the graph plots the expiratory flow rate by volume expired (until full expiration where air flow stops)

- Normal – rapid increase in flow rate, then gradual decrease until the end of expiration
- Obstructive – decreased peak expiratory flow rate with steeper reduction in flow rate after it peaks creating a characteristic dip (worse in emphysema – see dotted red line – due to small airway collapse)
- Restrictive – curve looks normal just smaller due to proportionally reduced flow rates (because total volume of lungs is restricted)