

ABCs of Ventilation in Anaesthesia

Aim

- To give you a step by step system to choose how to ventilate your patients
- To give you some information about ventilation of the sickest lungs as some principles may apply to healthy lungs as well

Terminology

Tidal volume (V_t) – volume of one breath

Minute ventilation (MV) – total volume of respiration in 1 minute

Respiratory rate (RR) – number of breaths per minute

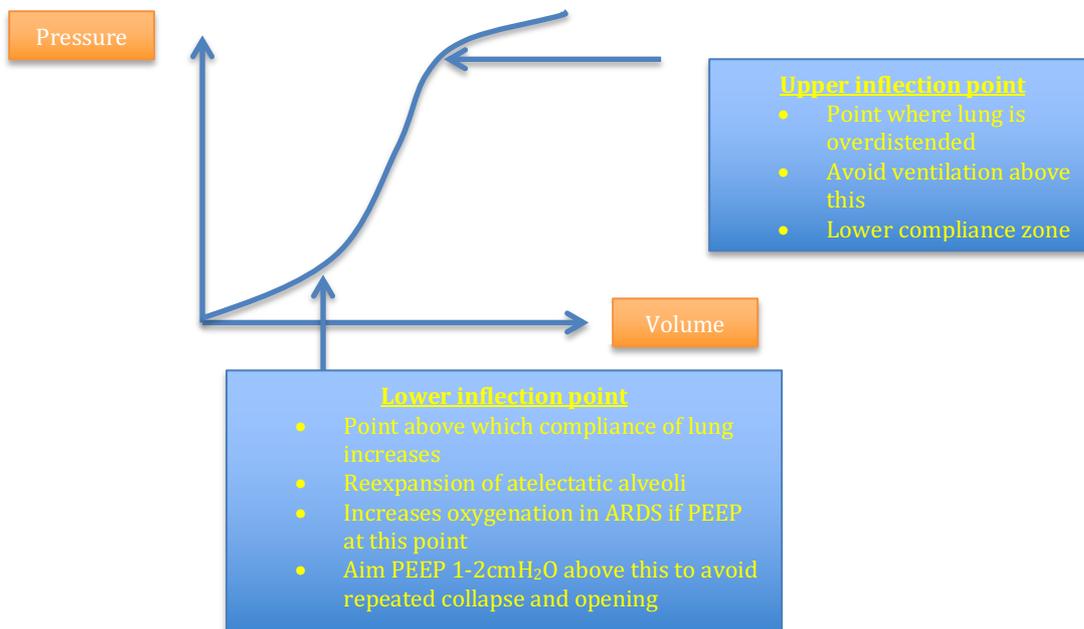
Positive End Expiratory Pressure (PEEP) – the pressure in the lungs that exists at the end of expiration.

Inspiratory: expiratory Ratio (I:E) – the ratio of time spent in inspiration to expiration. Usually set at 1:2 per 5 second IE cycle. (1.66: 3.33)

Inspiratory pause – interval from the end of inspiratory flow to the start of expiratory flow. Often as a percentage of inspiratory time.

Compliance – a measure of the distensibility of the lung. Shows a sigmoidal curve whereby at low and high lung volumes, the compliance is low. Lung volumes around functional residual capacity (FRC) have high compliance

Pressure volume graph



How does mechanical ventilation damage lungs?

1. Volutrauma
2. Barotrauma
3. Atelectrauma
4. Infection

How do we minimise damage for sickest lungs? (ARDS)

1. Low volume 6ml/kg ventilation (ARDSnet) (↓mortality (31vs40%) and ↑ ventilator free days (some evidence in non ARDS lungs))
2. Minimise plateau pressure <30cmH₂O
3. PEEP
 - Adv: ↑FRC. ↓collapse and derecruitment. ↓WOB
 - Disadv: alveolar overdistension. Deadspace ventilation. Hypotension. ↑ ICP
 - Ideal PEEP is that which prevents derecruitment and causes minimal overdistension
 - Aim at PEEP that gives highest PaO₂ and minimum FiO₂.
 - Practically I check the spirometry loop by pressing the relevant press button on the monitor – and find the PEEP that gives the best compliance.
4. Recruitment
5. Maintain oxygenation
6. Permissive hypercapnoea in sick lungs (eg asthmatics)
 - Oxygenation keeps the patient safe
 - Most patients will have minimal harm from high CO₂.
 - Over ventilation of sick lungs may cause more harm

Modes of ventilation

(For GE machines though similar modes will be available on other ventilators)

Select

- a) Mode – pressure or volume control
 - b) RR
 - c) PEEP
 - d) Choose amount of pressure support for patient triggered breaths
 - e) Fine details that I use: IE ratio, max pressure, trigger threshold (ask your consultant and test these)
1. Volume control ventilation (VCV)
 - Set the volume and RR
 - Check pressure limit (autoset to 40cmH₂O)
 - Constant flow
 2. Pressure control ventilation (PCV)
 - Set pressure and RR
 - Constant pressure
 - Decreasing flow
 3. Synchronized intermittent mandatory ventilation (SIMV)
 - Choose volume and RR
 - Choose pressure support for patient initiated breaths.
 - Any patient initiated breaths will either be pressure supported or volume controlled
 4. SIMV-PC (pressure control)
 - Like SIMV except set pressure, RR and pressure support for triggered breaths
 5. PSVPro (pressure support ventilation Pro)
 - Choose pressure support delivered for any patient initiated breaths.
 - If long period of apnoea – it will fall to back up mode with SIMV-PC mode with preset settings.
 6. PCV-VG (pressure control ventilation – volume guaranteed)
 - Set volume and RR and PEEP
 - The machine will use the lowest pressure to achieve the set VT.

Practical Principles

- 1) Volutrauma seems to be what causes harm in sick lungs so I generally target a maximum volume by using VCV or PCV-VG
- 2) In any circuit with a potential leak (eg. LMA or uncuffed paediatric tubes) part of the target volume may leak out.
Therefore I will use pressure targets (PCV or SIMV-PC). This ensures a stable volume is delivered.
- 3) If the high pressures are the limiting factor with ventilation (eg severe asthma or restrictive lung disease) a pressure controlled mode may be the best option to maximise tidal volume and therefore oxygenation.
- 4) At the end of a case when paralysis is not required for anaesthesia or surgery I will change to pressure supported mode eg. SIMV- PSV
This allows one to deliver a set number of breaths while also supporting any patient triggered breaths.
Once the patient is triggering frequent breaths I change to a completely pressure supported mode eg PSVPro or switch to the bagging circuit to allow the patient to breathe themselves.
- 5) Choosing FiO₂
 - Select <100% oxygen to avoid oxygen toxicity/atelectasis
 - Avoid very low FiO₂ as there will be minimal reserves if patient extubated risking hypoxaemia
 - Most anaesthetists choose somewhere between 40-80% FiO₂.
 - Consider the risk/benefit of oxygen level for each case* (see cases 11 and 12)

*Consider the patient who has a greater chance of dislodgement of ETT.
These are often cases where there is a shared airway (ENT/ airway surgery) or surgery where you have limited access to the ETT (prone surgery, large head and neck cases).

If the ETT is dislodged then:

- ⇒ If on a lower FiO₂, the time to hypoxaemia is shorter
- If on a higher FiO₂, the patient has greater reserves of oxygen when the ETT is dislodged. Therefore you will have more time to remedy the situation with a decreased risk of hypoxaemia.

*Consider a patient whose lungs are prone to worsening hypoxaemia (eg COAD with current infective exacerbation/ asthmatic with an exacerbation/ patient who has aspirated gastric contents on induction)

If the patient's lungs happen to deteriorate then:

- ⇒ If on a higher FiO₂, the sats will remain normal in spite of worsening oxygenation.
You will only realize there is a problem when the lungs are so bad that even a high FiO₂ is not enough to keep the sats normal.
At this stage you will have no room to increase the FiO₂ to keep the patient safe while you assess and treat the problem.
- ⇒ If on a lower FiO₂, the sats will fall as the lung condition worsens.
You will realize that something is occurring sooner.
You now have time to keep the patient safe by increasing FiO₂, while you assess and treat the problem.

- Regular assessments, auscultation and ABGs to calculate Aa gradient will also be valuable during case to assess worsening disease

Step by Step to Ventilator Settings

1. Does patient have airway requiring high pressures to ventilate (asthma, restrictive disease) or is there a leak in the circuit (LMA or uncuffed tube), or are you doing one lung ventilation?

Yes → choose Pressure control mode (PCV)
No → choose volume control mode (VCV)
2. Do you want the patient to eventually breath on their own

Yes → add a pressure support mode eg SIMV if VCV, or SIMV-PC if PCV or PSVPro
3. Tidal volume
 - Either dial up 6ml/kg for VCV or choose a pressure that roughly delivers 6ml/kg
4. Respiratory rate
 - Generally choose 12 breaths per minute.
 - If obstructive lung disease choose lower rate (eg. As low as RR of 4 if severe asthma)
 - If restrictive lung disease choose higher rate (eg as high as 20-40 may be required to compensate for very low volumes)
 - If you want EtCO₂ to increase to encourage spontaneous ventilations, use a lower RR
 - Titrate to EtCO₂ as required.
5. PEEP
 - Generally add 0-10cmH₂O of PEEP to maintain lungs at highest compliance
 - I use 5cmH₂O for most patients
 - Choose 0 peep if high pressures limit your ability to deliver a tidal volume (asthma, severe restrictive)
 - 5-10 in obese patients to maintain oxygenation and prevent atelectasis
6. FiO₂
 - Maintain Oxygen sats normal for patient or >94%
 - FiO₂ 60% for most cases

 - Is there difficulty accessing your ETT?
Yes → choose higher FiO₂ ~ 70-80%

 - Is there lung pathology that may worsen?
Yes → use lowest FiO₂ that safely oxygenates patient (>40% is usually safe)

Examples

What are your ventilator settings for these cases? (Answers over the page.. don't look!)

Case	Vent Mode	Vol/Pressure	RR	PEEP	Other
1) Eg. 50yo F 80kg for laparoscopic cholecystectomy Fit and well. ETT	VCV	500ml	12	5	FiO ₂ 60 Generally kept at 40-80% for most cases
2) 40yo M 70kg for open inguinal hernia repair - LMA					
3) 4yo M 20kg for supracondylar fracture requiring ETT					
4) 70yo M 90kg intubated for total hip replacement. You want the patient to start spont venting at end of case.					
5) 70yo M 120kg for laparoscopic radical prostate in steep head down					
6) 50yo F 150kg intubated for ankle orif. In VCV mode. Unable to achieve tidal volumes due to high pressure alarm/limit					
7) 20yo M 60kg severe asthmatic intubated in ED and transferred to ICU for ventilation.					
8) 60yo F 50kg with severe restrictive lung disease intubated for a fractured tibia					
9) 50yo M 70kg intubated for lap hiatus hernia repair. Has emphysema and known bullous lung disease					
10) 60yo M 70kg for One lung ventilation (OLV) eg thoracotomy					
11) 50yo M 90kg for laminectomy. Intubated and patient in prone position					
12) 80yo F 70kg with COPD and acute infective exacerbation for emergency laparotomy					

Answers

Case	Vent Mode	Vol/Pressure	RR	PEEP	Other	Notes
1) 50yo F 80kg for laparoscopic cholecystectomy Fit and well. ETT	VCV	500ml	12	5	FiO ₂ 60 Generally kept at 40-80% for most cases	
2) 40yo M 70kg for open inguinal hernia repair – LMA	PCV or SIMV-PC	10-15cmH ₂ O Aim for < 15 to avoid insufflation of stomach	5 I aim for low rate to allow patient to spont vent on their own	-		Switch to PSVpro or the bagging circuit once the patient starts to breathe on their own.
3) 4yo M 20kg for supracondylar fracture requiring ETT	PCV	10-15 cmH ₂ O Ensure volumes are approximately 120ml (6ml/kg)	12	5		
4) 70yo M 90kg intubated for total hip replacement. You want the patient to start spont venting at end of case.	SIMV PSV	500ml	3-5	5		Low RR will increase CO ₂ . This will stimulate her to breath spontaneously.
5) 70yo M 120kg for laparoscopic radical prostate in steep head down	PCV-PG (to minimise high pressures and maximise Vt.	500ml	12 or greater	5-10		Minimise EtCO ₂ to avoid cerebral vasodilation Ensure good paralysis.
6) 50yo F 150kg intubated for ankle ORIF. In VCV mode. Unable to achieve tidal volumes due to high pressure alarm/limit	Change to PCV or VCV-PG	Highest pressure that achieves a reasonable tidal volume ideally at <30cmH ₂ O But may be safe to got slightly higher	Small Vt means you need higher RR to achieve adequate MV. Eg >12	5-10 check for best volume per total pressure delivered.		Ensure good paralysis.
7) 20yo M 60kg severe asthmatic intubated in ED and transferred to ICU for ventilation.	PCV	30cmH ₂ O	4 need long expiratory time!	0-5	FiO ₂ 100% to maintain oxygenation. Give long expiratory time with very slow resp rate or IE of 1:4 or longer E time.	Priorities 1. Maintain oxygenation 2. Avoid gas trapping 3. Avoid barotrauma pressures <40cmH ₂ O 4. Permissive hypercapnoea Overventilation may cause gas trapping leading to arrest Permitting higher CO ₂ with underventilation may be safer. High CO ₂ is much more tolerated by the body.
8) 60yo F 50kg with severe restrictive lung disease intubated for a fractured tibia	PCV Allows maximum volume for given pressure	20-30 cmH ₂ O There will be a pressure point (upper inflection point) where further increase in pressure gives minimal increase in volume	High ~20 depending on MV achievable	-		Restrictive disease = low vol and high RR ventilation
9) 50yo M 70kg intubated for lap hiatus hernia repair. Has emphysema and known bullous lung disease	PCV VG Or PCV Or VCV	Start low with pressures or volume	~8	-		Set ventilator parameters before intubation Ensure APL valve is not on high pressure Avoid causing pneumothorax with high volumes or high pressures
10) 60yo M 70kg for One lung ventilation (OLV) eg thoracotomy	PCV	10-20 cmH ₂ O	12	5	FiO ₂ 100% often needed wwith OLV	PCV mode avoids overventilating any one lung when switching from 1 to 2 lung ventilation
11) 50yo M 90kg for laminectomy. Intubated and patient in prone position	VCV	500ml	12	5	FiO ₂ 80%	If ETT is dislodged, higher FiO ₂ allows a greater apnoeic time to solve airway issue
12) 80yo F 70kg with COPD and acute infective exacerbation for emergency laparotomy	PCV VG	400	~8	5	FiO ₂ 40%	Using a lower FiO ₂ that achieves a reasonable O ₂ sats allows you to detect hypoxaemic events before they escalate *