Vents

General

When to intubate:

1. Failure to oxygenate
2. Failure to ventilate
3. Failure to protect airway
4. Anticipated clinical course

Vent Settings:

- Tidal volume: Volume of gas entering lungs during inspiration. Generally keep this around 6 cc/kg of IBW even if the patient doesn't have ARDS.
- Respiratory rate: adjust this based on the gas (increase RR/ventilation to blow off CO2, decrease to retain).
- PEEP: minimum vent settings would be PEEP of 5, but patients may require higher PEEPS for further alveolar recruitment to improve hypoxemia.
- FiO2: minimum vent settings would be FiO2 of 40% or less. May require higher FiO2 for hypoxemia. Note: patients will often show up on a vent at 100% FiO2, this should be one of the first things that you try to wean to prevent oxygen toxicity.
- Flow: 60 L per minute will be set on a lot of vents. See the V = IR section for further discussion about flow.
- I:E ratio (inspiratory:expiratory time ratio): Typically is around 1:2 (expiration takes longer than inspiration). Keep an eye on this in obstructive lung disease (see "Vent Troubleshooting").

Modes of Ventilation (see "V = IR" section for in-depth discussion):

1. "Volume control": In an oversimplified way, you set a constant tidal volume and pressure is variable. Therefore you control the minimum minute ventilation given that you set the TV and RR. However, the patient can trigger additional breaths on top of the minimum minute ventilation that you set. In EPIC this mode is confusingly written as "AC".
2. "Pressure control": In an oversimplified way, you set a constant pressure and tidal volume is variable. You still set a RR, but the patient can still trigger additional breaths on top of the set RR. This is also technically an "AC" mode of ventilation which is why EPIC calling volume control "AC" is confusing.
3. "Pressure support": There is no set RR, only a set pressure. **The patient must trigger the vent**; they initiate all their own breaths. If the patient doesn't breathe, the vent won't do a single thing (other than automatically flip back to one of the above modes if the patient is apneic for too long to prevent the patient from dying).

Hold Maneuvers:

1. End-inspiratory hold (press the button on the vent): calculates the plateau pressure (this should be less than 30, especially for ARDS patients). See "Vent Troubleshooting" for a more physiological discussion about peak and plateau pressures.

2. End-expiratory hold (again there's a button): calculates the PEEP. See "Vent Troubleshooting" for a discussion about auto-PEEP.

V = IR and Vent Settings (from Hooman Poor's vent talk)

*Disclaimer: Not all people think about vents the way Hooman teaches them. I feel like I have a much better understanding of vents after hearing this talk, but other attendings use somewhat different thinking and terminology so just be aware that this may not be for all audiences.

It's back! Let's look at V = IR from the perspective of ventilators.

ΔP (aka inspiratory pressure – alveolar pressure) = flow (aka Q) x resistance

Rearranging the equation leads to
Q = (Pinsp – Palv) / R

- For people not on vents, Pinsp = atmospheric pressure (aka 0 since you're not getting any positive pressure to help you breath) and Palv is negative as your diaphragm contracts downwards.
- So in a person not on a vent, as they take a breath Pinsp is 0, Palv becomes more negative, and therefore there is flow into the lungs (zero minus a negative number makes a more positive number).
- Conversely, if a person is not on a vent and they exhale Palv becomes more positive and therefore there is flow out of the lungs (because they create negative flow).
- For patients on vents, the Pinsp will be positive (ventilators give breaths with positive pressure) and Palv will vary depending on if the patient is taking breaths themselves or not.

Let's put the equation on the back burner for just a little bit to talk about some terminology.

If you're a vent, you need to know a few things in order to give a patient a breath.

1. <u>When should I give a breath?</u> (Let's call this the **Trigger**)
2. <u>How should I give a breath?</u> (Let's call this the **Target**)
3. <u>When should I stop a breath?</u> (Let's call this the **Cycle**)

Trigger: here are the ways that a vent can know when to start a breath

1. Time (set a minimum respiratory rate and if the patient doesn't breath the vent will automatically give them a breath); <u>**this is the "control" in "assist control"**</u>
2. Flow/Pressure (the ventilator senses that the patient is taking a breath either by a decrease in pressure or a decrease in the flow returning to the vent and gives a breath); <u>**this is the "assist" in "assist control"**</u>

- Note: what happens if a patient is on AC and their vent RR is set at 20 but their physiological RR would be 16? **Every single breath they take will be a control breath** (aka they are not initiating any of their own breaths). Conversely, what would happen if that same patient starting breathing at 30 and you increased their vent RR from 20 to 24? **Nothing would change, the patient would still breath at 30 and every single breath would be an assist breath.**

Target: here are the ways that a vent can know how to give a breath

1. Set a flow (Q from the V = IR equation)
2. Set a pressure (Pinsp from the V = IR equation)

Cycle: here are the ways that a vent can know when to stop a breath

1. Volume (stop a breath after a set tidal volume)
2. Time (stop a breath after a set time)
3. Flow (stop a breath after flow decreases to a certain percentage of peak flow)

Ok, so let's talk about the three most common modes of ventilation (and the only modes that are really used in the MICU) in terms of the above variables and the V = IR equation.

Volume Control (or more accurately Volume-Cycled Assist Control)

1. Trigger: AC; this means that the ventilator is going to give the patient a minimum number of breaths per minute (you set a RR) but the patient can initiate breaths on top of that minimum respiratory rate.
2. Target: Flow; the ventilator gives a fixed flow until it is told to stop.
3. Cycle: Volume; this means that the ventilator will stop a breath whenever the patient receives the set tidal volume.
4. **Pressure is variable!**

<u>Clinical examples using Q = (Pinsp – Palv) / R</u>

If the patient makes a big inspiratory effort: Palv decreases but Q is fixed (the target is fixed flow!). R does not change. Therefore, if Q is fixed and Palv decreases then **Pinsp must decrease**. So if your patient is taking a breath, the **positive pressure from the vent will decrease**.

If the patient coughs: Palv increases. Q is still fixed (again since it's the target), and R does not change. If Q is fixed and Palv increases then **Pinsp must increase.** So if your patient coughs, the **positive pressure from the vent will increase** (and if your peak pressures increase too much, the 5-tone vent alarm that you'll hear in your dreams after being in the MICU for too long will sound).

If the patient bites the tube: R will increase. Q is still fixed (again since it's the target), and Palv does not change. Therefore **Pinsp must increase** aka the **positive pressure from the vent will increase** to overcome the increased resistance of the tube (and the vent alarm will sound).

Pressure Control (or more accurately Time-Cycled Assist Control)

1. Trigger: AC (same as above). <u>Many people say "AC" to refer to volume control only but Pressure Control is also an AC mode!</u>
2. Target: Pressure; the ventilator gives a fixed inspiratory pressure until it is told to stop.
3. Cycle: Time; the ventilator will stop a breath after a set amount of time.
4. **Flow is variable! (Aka volume is variable).**

Clinical examples using Q = (Pinsp – Palv) / R

If the patient makes a big inspiratory effort: Palv decreases but Pinsp is fixed (since it's the target; the ventilator gives the same pressure in this mode no matter what else happens). This results in **increased flow** (and therefore increased volume). So if your patient is taking a breath, the **tidal volume will increase**.

If the patient coughs: Palv increases. Pinsp is fixed (again since it's the target). This results in **decreased flow (and therefore decreased volume)**.

If the patient bites the tube: R will increase. Pinsp is fixed (again since it's the target). This results in **decreased flow (and therefore decreased volume)**.

Pressure Support

1. Trigger: Assist only (aka the patient has to initiate all breaths. If the patient doesn't try to take a breath the vent will do nothing).
2. Target: Pressure; the ventilator gives a fixed inspiratory pressure until it is told to stop. This is the "pressure support" from the vent.
3. Cycle: Flow (also known as "E sense" in this mode of ventilation); the ventilator will stop giving the pressure after flow decreases to a set fraction of peak flow (usually 25%).
4. As in pressure control, **flow is variable (aka volume is variable).**

Clinical examples using Q = (Pinsp – Palv) / R

If the patient makes a big inspiratory effort: Palv decreases. Pinsp is fixed (since it's the target). Therefore Q will increase, which leads to an increased tidal volume. This means that the bigger breaths the patient takes (aka the more negative their Palv becomes), **the less "pressure support" (or Pinsp) they require to maintain good tidal volumes.** This is why we do pressure support trials to determine if patients are able to take good breaths on lower and lower Pinsp (pressure support). If a patient is on pressure support of 5 (or zero!) and they are pulling good tidal volumes, you know from a purely neuromuscular perspective that they're probably ready for extubation (see section on extubation for more details).

Vent Troubleshooting

1. High peak pressures
   - Decrease in compliance of the respiratory system (lung compliance, stiff chest wall, ascites, pregnancy, pneumothorax, etc.) and increase in airway resistance cause increased pressures; to differentiate the two we look at plateau pressure, which is a measure of **lung compliance** (by definition it is the pressure required to overcome lung compliance alone).
   - How do we calculate plateau pressure? V = IR is back yet again! Ppeak – Pplat = flow (Q) x resistance (R), meaning Ppeak = Q x R + Pplat

- Based on the above equation, we can see that the vent will be able to calculate the plateau pressure based on an **end-inspiratory hold maneuver**; pausing inspiration without allowing expiration means that Q (flow) equals zero. Zero times any amount of resistance will still equal zero, so the pressure measured by the vent will equal the plateau pressure.
- Therefore if a patient has a high peak pressure, use the plateau pressure to determine whether there is a problem with lung compliance or airway resistance.
    - **Low plateau pressure with high peak pressure means problem with airway resistance:** examples include mucous plugging, biting the tube, bronchospasm
    - **High plateau pressure with high peak pressure means problem with lung compliance:** examples include pneumothorax, pulmonary edema, ARDS
- Solutions: depends on the problem! Can also
    - Increased airway resistance: consider suctioning, nebs to treat potential bronchospasm, sedation if patient is agitated and biting tube
    - Decreased lung compliance: evaluate for ARDS and pneumothorax, consider diuresis for pulmonary edema

2. Vent dyssynchrony
    - Most commonly caused by agitation but can also be due to patient sensation of air hunger (meaning that vent settings need to be adjusted)
    - Solutions:
        - Increase sedation
        - Change vent settings (increase tidal volume or flow, etc.)
3. Auto-PEEP in patients with obstructive lung disease
    - "Auto-PEEP" (or intrinsic PEEP) occurs with breath stacking, or when a patient initiates another breath before complete expiration of the previous one.
    - This is bad because you progressively increase the alveolar pressure, which if uncontrolled will eventually lead to barotrauma (worst-case pneumothorax) as well as decreased venous return (worst-case complete cardiovascular collapse)
    - Diagnosis: **end-expiratory hold maneuver**
        - Auto-PEEP will be the pressure calculated from the end-expiratory hold maneuver minus the applied PEEP on the vent
    - Solutions:
        - **Decrease RR** (gives patients more time to expire, which increases the I:E ratio)
        - **Increase max flow** (should make the inspiratory phase shorter by giving higher flow, so for a set RR expiratory time will increase, which increases the I:E ratio)
        - **Decrease TV** (decreases inspiratory time and less volume to fully exhale)
        - Worst-case scenario you can detach the patient from the vent and actually press on the patient's chest to help push the extra air out of their lungs.
4. Desaturation
    - Potential causes: self-extubation, endobronchial intubation, pneumothorax, worsening of causes of hypoxemic respiratory failure

- 5 things cause hypoxemia: shunting, diffusion abnormalities, hypoventilation, V/Q mismatch, and decreased PiO2. If a patient has hypoxemic respiratory failure at least one of these things is wrong.

- Solutions:
  - Assess for potentially reversible causes (Is the tube still in place? Does the patient have bilateral lung sounds? How does the CXR look? If the patient was intubated for hypoxemic respiratory failure, can we improve any of those causes with interventions like diuresis?)
  - Increase FiO2
  - Increase PEEP to recruit more alveoli
  - Worst-case scenario you can detach the patient from the vent and manually bag them through the tube. If the tube is out, remove it completely, bag them, and call Anesthesia.

When Can You Extubate?

Consider extubation when most of the following criteria are met:

1. Resolution of the reason for intubation
   - Fix the underlying cause! If it's not fixed or significantly improved, the patient will just get re-intubated.
2. Spontaneous breathing trial
   - If you want to get technical, a real spontaneous breathing trial would mean putting the patient on a T piece and letting them breath completely on their own.
   - In the MICU, our "SBTs" are done on pressure support to assess whether patients are able to pull good tidal volumes on a low amount of pressure support (see "V = IR" section for physiology). See discussion of RSBI below.
3. Patient is oxygenating well on minimal vent settings
4. Mental status, following commands
5. Intact gag and cough to prevent aspiration
6. Minimal respiratory secretions
7. Cuff leak test
   - The ETT has an inflatable cuff that seals off the trachea.
   - If a patient has laryngotracheal edema, when the cuff is deflated the patient may not have a cuff leak (gurgling, able to vocalize, and difference in inspiratory/expiratory tidal volumes).
   - If a patient has no edema, when the cuff is deflated there should be space between the ETT and the airway allowing for air flow around the tube. This allows for the gurgling/vocalization mentioned above.
     - To actually determine the cuff leak, you can measure the inspiratory tidal volume prior to cuff deflation and the expiratory tidal volume after deflating the cuff. The idea is that the ventilator will give you a tidal volume but the expiratory tidal volume that the vent senses should be lower than what was given because a certain portion of the tidal volume goes around the ETT when the cuff is deflated. Cut-offs for a positive cuff leak test are the inspiratory TV minus the

expiratory TV being > 110 cc or at least 10% of the inspiratory TV, but you only really need to worry about checking these for high-risk patients.

8. Rapid Shallow Breathing Index (RSBI)
   - A landmark paper by Yang and Tobin published in 1991 in NEJM created the RSBI which has been used for the past several decades as a method of identifying patients who are at risk of vent weaning failure.
   - RSBI = RR / TV (in liters, so remember that a TV of 500 cc should be coverted to 0.5 L)
   - Physiologically, if someone is breathing at a normal rate and pulling good tidal volumes they are more likely to be successfully extubated and their RSBI will be low. Conversely, if someone is tachypneic and breathing with low tidal volumes their RSBI will be high.
   - **A RSBI of greater than 105 predicts vent weaning failure.**
   - Big caveat: Yang and Tobin formulated the RSBI using patients who were placed on spontaneous breathing trials **using T-pieces** (aka the patient is completely removed from the vent and therefore has no ventilatory support). In the MICU our SBTs are conducted on progressively decreasing pressure support on the vent. Multiple studies have shown that RSBI scores can vary widely depending on the amount of pressure support and even with different amounts of FiO_2.
   - Overall, use the RSBI as an additional piece of evidence in your decision to extubate, not as a highly validated clinical tool that you can solely rely upon. It's probably better to just take a gestalt view; if a patient is tachypneic and taking small tidal volumes they're probably not going to do well.