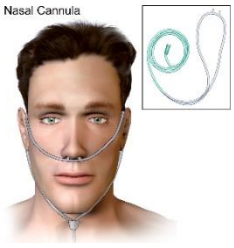
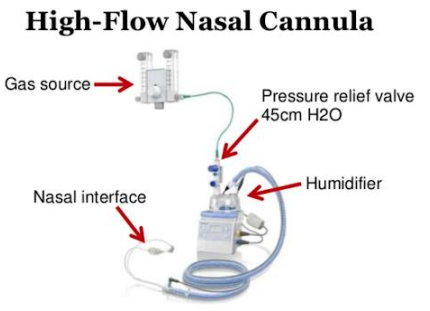
- To start off with, a few stats based on what we know so far about COVID19 (as at 31/3/2020)
    - 80% of those who are infected will either be asymptomatic or not require hospitalisation
    - 15% will require hospitalisation
    - 5% will require intensive care admission
    - Anywhere between 0.5-3% of people will die, largely depending on testing and how overwhelmed the health care system is. As resources are overwhelmed, deaths increase in a vicious cycle.
- What these stats tell us is most patients with COVID won't actually require hospitalisation and airways management – the vast majority of patients will need supportive therapy at most.
- When people are hospitalised, the interventions usually required include
    - Oxygen therapy – currently the only therapy proven to be beneficial for COVID
    - Sometimes fluids (if they're presenting with GIT symptoms)
    - Sometimes antibiotics for secondary bacterial pneumonia
    - Sometimes PEEP (we'll get onto this in a second) – this can be delivered by non-invasive ventilation (NIV) or invasive ventilation (intubation, tracheostomy)
- Airways management 101
    - As with everything in medicine, you start with the least invasive method which will result in improvement, and escalate as necessary
        - Nasal prongs – limited by how much oxygen you can deliver
            - 

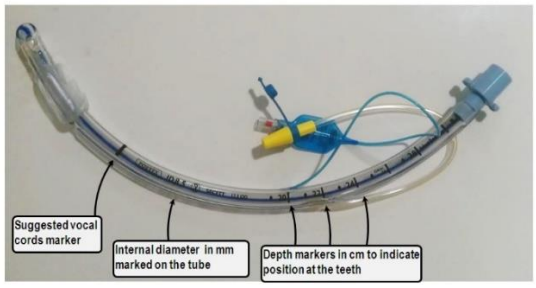
Source: Wikimedia Commons
        - HFNC – high flow nasal prongs increase the amount of oxygen you can deliver by increasing the flow (ie. Volume, see ventilation management). The increase in volume being provided also has the beneficial effect of increasing pressure, specifically providing some positive end expiratory pressure (see ventilation management).
            - According to the ANZICS COVID19 guidelines (available in resources), HFNC is classed as an aerosol-generating procedure. As such, airborne precautions are required for these patients
            - 


Source: EM Docs, RT magazine
        - CPAP – continuous positive airway pressure. In CPAP a certain amount of pressure is constantly applied to generate PEEP, which helps to keep airways splinted open. It differs from BiPAP in that CPAP is a consistent level of pressure, whereas BiPAP changes the pressure based on if the patient is inspiring or expiring.
            - CPAP appears (anecdotally) more beneficial than BiPAP in COVID patients, which makes sense as ARDS usually responds best to CPAP. However, it should be noted that NIV is NOT recommended in COVID19 as per the ANZICS guidelines– this is because failure rate is high, and often the only thing it does is delay intubation. However, protocols vary based on location and stage in the outbreak. Many sources from the US where overwhelming numbers are being seen are recommending CPAP

over intubation in order to preserve resources. Watch this space, it's likely to continue to change. Early intubation is preferred for the reasons outlined below

- CPAP generates aerosols, especially if the mask is incorrectly fitted. As CPAP is often uncomfortable for patients, they often try and adjust the masks as they breath which can result in seal breaks and ejection of virus particles into the environment. If possible, a "helmet" can be useful (author note: I've seen these being used in Italy and other parts of Europe but I'm not sure if the helmets are available here).
- Viral filters should be added to the CPAP circuit in order to reduce risk of viral spread, especially if CPAP ventilators are being shared due to low resources
-  Source: Wikipedia, Intersurgical

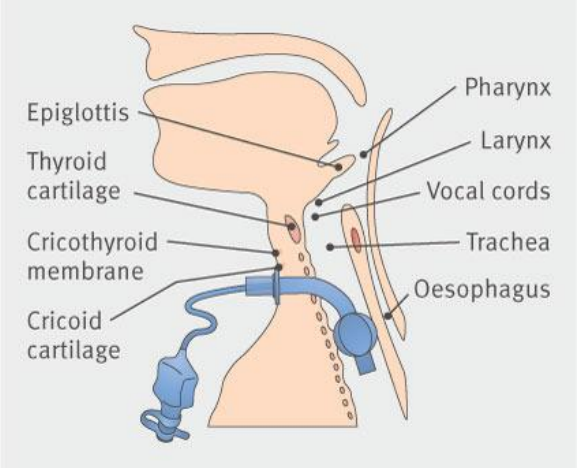
▪ Invasive ventilation

- Intubation with Endotracheal tube – current evidence supports intubation early so it can be done in a calm and controlled manner, with experienced physicians, appropriate PPE, some level of physiological reserve, and ideally video-assisted laryngoscopy
- 

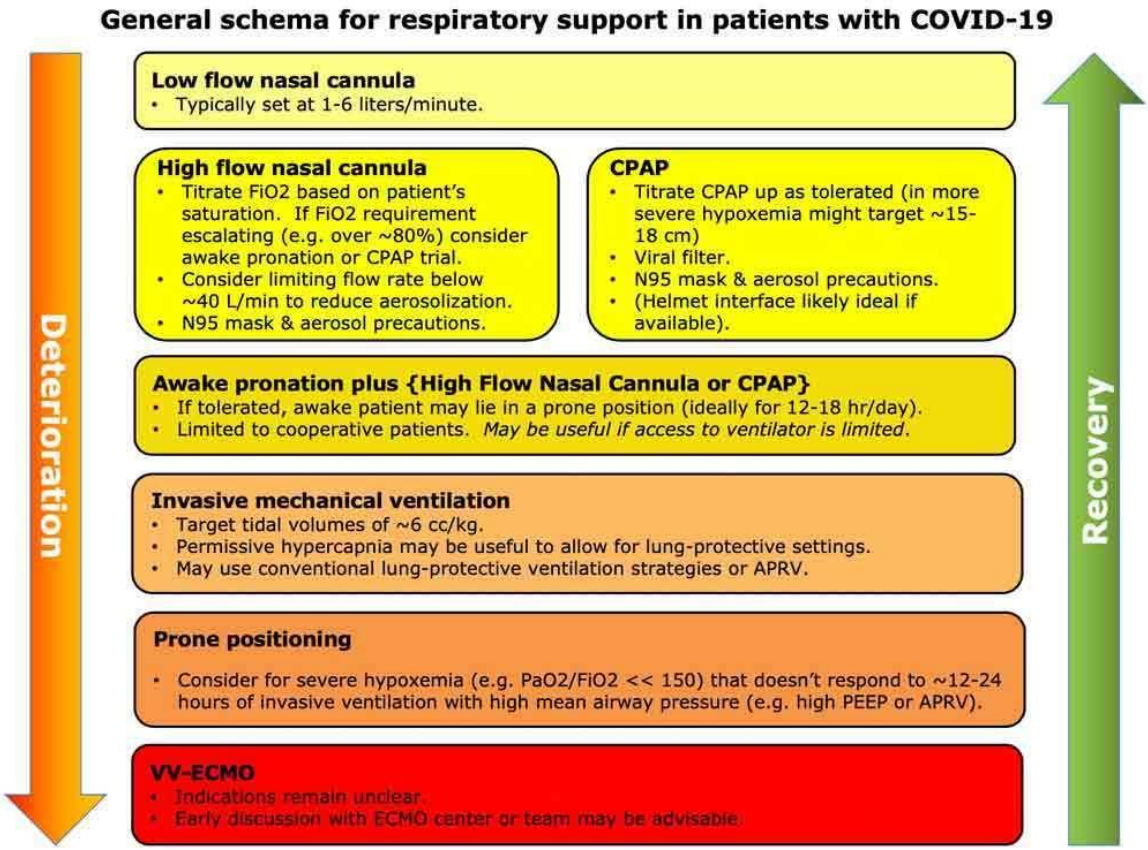
Source – Deranged Physiology
- Intubation requires skilled staff, PPE, and ventilators. It also requires patients to be sedated to tolerate the tube. Currently, ventilators are one of the biggest worries. Many older models (that are still perfectly functional) are being pulled out of storage in anticipation of a surge of patients. Should we run out, then the discussion of ventilator sharing between patients has been discussed (further reading and an explanation are included in the next sections). It should be noted that splitting ventilators between multiple patients isn't best care, which is why we don't do it usually. However, it might end up being that a shared ventilator is better than no ventilator
- Whenever we intubate a patient, we should be thinking about a plan for extubation. It appears patients with COVID require extensive periods of intubation, and early on appear to get better for a period on the ventilator before deteriorating. Early extubation in this period is tempting, but when PEEP is reduced a relapse in symptoms can be seen. It's better to keep them intubated for longer in anticipation of the deterioration after initial improvement, and to prevent the need for reintubation (and the increased risk of transmission that occurs with this). A recent case series out of Seattle suggests median duration of intubation is 10 days, with the earliest survived extubation occurring after 8 days.
- LMA (laryngeal mask airway) are not recommended because
  - (a) they are not a definitive, secured airway (ie. They can be relatively easily dislodged, especially if we're proning patients (see below)).
  - (b) the cuff seal isn't as secure, and cuff leak could lead to the release of virus

Source: Teleflex

- Tracheostomy is considered for patients who are on ventilators long term, as the ETT can irritate the laryngeal folds and result in strictures if left long term. I can't find any formal guidelines on this at the moment.



Source: The BMJ



Source: Internet Book of Critical Care by @PulmCrit (Josh Farkas)

- Ventilation management 101
    - The amount of oxygen delivered to the patient depends on two things – the **fraction** of inspired oxygen (FiO2), which is the concentration of oxygen in the air supplied, and the **volume** of air. For example (you wouldn't use these volumes on an actual patient), you could be ventilating a patient on 10L at 50% or 5L at 100% and be providing the same amount of oxygen (ignoring other physiological constraints like dead space)
    - There are several variables we control with the ventilator. Some of the *key* ones are
        - Tidal volume – how much air the ventilator moves in and out with each breath. Ideally this should be 6ml/kg based on ideal body weight (because lungs are based on height rather than weight). This can vary based on the condition – if the volume is too great we can cause barotrauma such as pneumothorax
        - Respiratory rate – can be set so the patient has a minimum number of breaths a minute
        - Positive End Expiratory Pressure – PEEP is one of the most beneficial things in COVID. PEEP splints open airways that otherwise collapse with exhalation. When an alveolus collapses, it requires a lot of force to open it back up. If lots of your alveoli close, your restrictive work of breathing increases, and your area for gas exchange decreases. PEEP increases the pressure which the person breaths out against (a little like breathing out against pursued lips, which is why we see people with COPD do it), and in doing so it keeps those airways open that would otherwise collapse. Click here for an excellent video which demonstrates PEEP. COVID causes microairways to collapse, so is very responsive to PEEP. This is backed up by the ANZICS guidelines recommending relatively high levels of PEEP (>15cmH_2O, usually we use 5-12)
        - Inspiratory pressure above PEEP – this is the pressure that helps push air in during inspiration (remember PEEP is expiratory only – inspiratory pressure is like sticking your head out the window of a car on the freeway and breathing in).
        - FiO2 – discussed above
    - There are also several modes
        - Spontaneous/Supported – patient controls when the ventilator fires, and the ventilator provides help. If the patient is taking shallow breaths, the ventilator can assist with taking deeper ones but provides less support than assisted
        - Assisted – When the patient starts sucking in, the ventilator kicks in and delivers a full breath. If the patient is sedated and not breathing enough, the ventilator will fire to ensure the minimum respiratory rate is set
        - Controlled – the ventilator controls rate and depth of ventilation, typically the patient is heavily sedated including with paralytics
        - If the patient is "fighting" the ventilator, either the settings need to be modified for the sedation deepened
    - And finally, we can control what the ventilator is focussed on delivering (and what triggers it to stop pushing)
        - Pressure mode – based on peak inspiratory pressure; the ventilator is limited by a maximum pressure. Once that pressure is hit, it doesn't matter how much volume has been delivered, the ventilator will stop. This method tends to prevent barotrauma, especially in patients whose lung compliance may be low
        - Volume mode – the ventilator ignores pressures and aims to deliver a set volume. This can work in some obstructive conditions, where we don't necessarily mind a higher pressure as long as we can deliver a minimum amount of oxygen back into the patient's lungs.
    - Remember – respiratory physiology doesn't stop just because we intubate a patient. We need to continue to consider intrathoracic pressures and the effect on venous return and cardiac output, as well as pre-existing lung conditions which can change lung compliance, gas exchange surface etc. Physiological dead space is increased whilst on a ventilator due to the length of tubing running into the ventilator

- Ventilator Sharing
    - This is a controversial area, with various physicians posing different views. There is one main consensus – sharing one ventilator amongst multiple patients is not the gold standard and should be avoided wherever possible. Really ventilator sharing should only be considered when there are no ventilators left, when less than perfect ventilator support is better than no support. That's the angle this post will then go on – a hypothetical set up for a worst-case scenario. Most of this setup is based on what is described by Josh Farkas in his Pulmcrit post
    - If we're going to have multiple patients on the same ventilator, the first thing to consider is which patients go together. Logically, the patients with similar degrees of illness, similar size, and similar comorbidities would be best suited to go together. Degree and prognosis of illness will probably be the biggest determinant of who shares ventilators with who
    - All patients on any kind of circuit should have a viral filter in the circuit. This doesn't change if ventilators are shared – it's important not just for the patients but also for the treating team if part of the circuit disconnects
    - When it comes to modes of ventilation, all of these patients should be deeply sedated and on a fully controlled mode – this stops one patient from triggering the ventilator to provide all of the patients hooked up to it a breath. This also ties in with selecting people with a similar degree of illness – they'll likely have similar requirements in terms of respiratory rate, FiO2, PEEP, etc.
    - The ventilator should be set to a pressure cycled ventilation. In a volume cycle mode, if a tube connecting one of the patients kinks then all of that patient's air will be redistributed to the other patients, potentially resulting in barotrauma. Having the ventilator set up with pressure limitations means that a kinked tube won't affect the other patients
    - There are physical constraints with having multiple patients hooked up to one ventilator – where is there an area large enough to facilitate 4 ICU beds huddled around a ventilator? Keep in mind we need to have these patients as close to the ventilator as possible – every time we extend the tubing between patient and ventilator we increase physiological dead space and therefore decrease gas exchange.
    - Because of the increased dead space and decreased volume of ventilation (because they're on a pressure cycled mode), these patients will have to tolerate some degree of hypercapnia. This will also play into which patients can split ventilators
    - Ventilators are very good at letting us know when something isn't going right (they almost never stop beeping), allowing us to provide very high quality of care to an individual. When we put multiple patients on a single ventilator, we lose that level of feedback. Now patients can potentially deteriorate further before it's detected, and we can lose the ability to tell which patient requires the extra support that's causing the machine to beep (especially because these patients will all be heavily sedated). Therefore, these patients still require a very high level of care.
- Proning
    - Often, the posterior lung fields are affected more than the anterior lung fields
    - This means that there is significant V/Q mismatch – gravity pulls blood to the posterior lungs when the patient is on their back, so the airspaces which are most affected by the pneumonitis/ARDS are the ones with all the blood. The lung fields which are unaffected have poor blood supply, so their ventilation is greater than their perfusion.
    - The solution? Roll these patients prone (onto their stomachs). The anterior lung fields still maintain good ventilation and now gravity pulls more of the perfusion to these areas, helping to improve V/Q mismatch
    - There's a theoretical benefit of adding nitric oxide or prostacyclin to the inhaled gases, so that the areas of the lung which are ventilating more will get more exposure to these vasodilatory agents and thus further increase their perfusion. This is discussed in the ANZICS guidelines, and whilst there is no evidence for its use in COVID, it may be worth trying in patients who have a chance of responding

A CT chest of a COVID19 patient demonstrating posterior lung field infiltrates whilst leaving the anterior lung fields clear. Source: Dr Fabio Macori via Radiopedia

- Further resources/Bibliography
    - ANZICS COVID19 Guidelines - https://www.anzics.com.au/wp-content/uploads/2020/03/ANZICS-COVID-19-Guidelines-Version-1.pdf
    - Internet Book of Critical Care: COVID19 -https://emcrit.org/ibcc/COVID19/
    - Rebel EM: Simplifying Ventilation (highly recommend this source for explaining the physiology behind ventilation settings) - https://rebelem.com/simplifying-mechanical-ventilation-part/
    - EmCrit: Crit Care for Non-Intensivists - https://emcrit.org/emcrit/critical-care-for-non-intensivists/
    - Good intro/layperson guide to ventilators - https://www.theguardian.com/world/2020/mar/27/how-ventilators-work-and-why-they-are-so-important-in-saving-people-with-coronavirus
    - Lots of ICU resources/protocols, including some on shared ventilators - https://covid19-icu.net/
    - Another list of intensive care resources - https://www.reddit.com/r/IntensiveCare/comments/fjtas3/covid19sarscov2_critical_care_management/
    - https://emcrit.org/pulmcrit/cpap-covid/
    - https://emcrit.org/emcrit/covid-airway-management/
    - Specific resources on split ventilators
        - https://emcrit.org/pulmcrit/split-ventilators/
        - https://emcrit.org/pulmcrit/pulmcrit-wee-why-the-sccm-aarc-asa-apsf-aacn-chest-joint-statement-on-split-ventilators-is-wrong/
        - https://emcrit.org/emcrit/alternatives-to-vent-splitting-and-the-safest-vent-splitting-methods-in-covid19/
        - https://litfl.com/should-we-put-multiple-covid-19-patients-on-a-single-ventilator/
        - Article written by docs involved in the Las Vegas shooting, which rapidly (and acutely) overwhelmed crit care capacity and resulted in the need for ventilator splitting https://epmonthly.com/article/not-heroes-wear-capes-one-las-vegas-ed-saved-hundreds-lives-worst-mass-shooting-u-s-history/