Can 1 Ventilator Treat 2 Patients?

By Chuck Dinerstein, MD, MBA — March 26, 2020

As the number of patients requiring ventilatory assistance to survive COVID-19 rises, and with no new ventilators in sight, a "Hail Mary" technique is starting to be used. Can a machine designed to help one patient be reconfigured to support two or more? And can it protect society at large, even just a bit, from surging hospital admissions?

Oxygen moves in and out of our bloodstream by the passive process of diffusion – higher amounts moving towards lesser amounts in an attempt to equalize. Our breath, serving to refresh the reservoir that we call our lungs, is a dance of chemistry and physics acted out by our muscles, nerves, and the functional component of lungs, the alveoli. To understand Covid-19's respiratory complications and the subsequent need for ventilators, we need to know a bit more about that dance.

When we inhale, the intercostal, between the ribs, respiratory muscles, and the diaphragm expend energy to expand the size of our chest bring air through our mouth and throat into our lungs. With exhalation, a primarily passive process, the muscles, and lung tissue snap back towards their original volume, pushing air out. The air that comes and goes in that exchange is the tidal volume and serves to replenish a higher amount of oxygen to the lungs where it can diffuse into the bloodstream. While we can increase our tidal volume by taking a deep breath, for a variety of reasons, increasing our rate of breathing, the respiratory rate, replenishes that reservoir more
quickly. Having brought air all that distance, it is oxygen passively crossing the alveoli’s membrane into the bloodstream, that last mile, that is hardest. Oxygen can only travel a short distance, so if the alveolar layers thicken, the gap becomes too great, and oxygen levels in the bloodstream decline. In this description, tidal volume, respiratory rate, and oxygen’s ability to diffuse, orchestrate the delivery of oxygen to the blood. These are the variables that we can affect, to a greater or lesser degree, when Covid-19 "attacks" our lungs.

A symposium to discuss our capacity to "surge" ventilatory assistance in the presence of a health disaster took place in 2007. They considered a number of scenarios, including a pandemic. Each scenario requires different respiratory care and ventilator management. In the face of a pandemic, they correctly predicted people would present to the hospital with signs of respiratory infection and distress. They also predicted that patients would present "with low lung compliance, hypoxemia, and acute lung injury or ARDS." What does that mean?

Hypoxemia is straightforward, referring to abnormally low levels of oxygen in the blood in relation to the amount of oxygen provided to the lungs. We are as dependent upon oxygen as plants are to sunlight.

Acute respiratory distress syndrome, ARDS, is a final pathway for many infectious and traumatic events. The response of the lungs, in this case, to coronavirus, is to summon the immunologic cavalry. The immunologic response unintentionally thickens those alveolar membranes, making it more difficult for oxygen to diffuse. The inability to deliver oxygen from the bloodstream to our organs will subsequently cause them to fail over time, tightening the death spiral. [1]

The thickening of the alveoli makes the lung stiffer, creating more work for our respiratory muscles to expand the lung during inhalation; and reducing the elastic recoil of the lungs that expels air with exhalation. These two effects cause the tidal volume to fall. The rate of breathing increases to compensate, but the muscles already under additional stress, tire; you cannot breathe rapidly, termed tachypnea, for long periods. Mechanical ventilation seeks to restore adequate oxygenation

**Mechanical ventilation**

Ventilators can manipulate the volume of air delivered, at what rate, and with how much pressure. Setting those variables to optimize oxygenation in both science and art. In the case of ARDS, you seek to increase tidal volume by increasing volume delivered by increasing the push or pressure of air into the lungs, while simultaneously increasing the oxygen content you are providing, from the 20% in the atmosphere to as much as 100%. Only two problems, our lungs can only tolerate so much expansion and pressure before they are injured, further compromising their structural function; and oxygen at high concentrations is a toxin broadening damage to alveoli. [2] Once those limits to ventilation are exceeded, oxygenation fails, and we die. In a fraction of cases, we can let the lung rest and recovery by taking over oxygenation completely, using extra-corporeal membrane oxygenation (ECMO), a much more sophisticated, invasive, less available option. [3]

Covid-19 can result in a higher incidence of ARDS than we can accommodate with our current supply of ventilators. Hence, the idea that we could hook more than one patient at a time to a ventilator is a stopgap to increase capacity while we wait for more ventilators to arrive. As New York’s Governor Cuomo said. "We use one ventilator for two patients. It's difficult to perform, it’s
experimental, but at this point, we have no alternatives." With a brief overview of respiratory physiology and the deleterious effects of ARDS in hand, let us look at what science we know about this experimental alternative.

Proof of concept

The idea was reported in the literature in 2006 as a proof of concept, feasibility study. It involved a DIY approach for a situation where you needed more ventilators than you had. The authors demonstrated that you could take one ventilator and using standard parts, available in the hospital in real-time, ventilate two simulated lungs. They proved you could "McGyver" a two-for-one deal; the ventilator was capable of delivering the pressures and volumes needed for two simulated patients. The Youtube video, by one of the co-authors, is here [2] and was sparked by Covid-19.

One example of the rerouting involved.

In my admittedly abbreviated literature search, I found only two references to linking multiple animals or humans to one ventilator. The first involved two people injured in the mass casualty Las Vegas shooting that required emergency intubation and ventilation for their injuries, subsequently connected to one ventilator with a Y connection. This anecdotal report involves a very different lung injury; it is not pertinent.

The second study involved four sheep, which share much of our pulmonary physiology. Four 70-kilogram sheep were anesthetized, had breathing tubes placed in their lungs, and were hooked
through 4 separate ventilator circuits to one ventilator. In addition to ventilating the sheep, the researchers cleared airways and modified the volume and pressure settings as we usually do for patients – a study of what might be practical. The sheep were successfully ventilated and oxygenated within clinically reasonable limits of the equipment for 12 hours. As they wrote, "We chose 12 h because ventilators from US Strategic National Stockpile can be delivered within this time frame."

Will it work?

There are several limitations of the technique uncovered by this study that bears directly on its current applicability. Ventilators can deliver a breath at a rate we set, or in response to a patient's initiation of inhalation. You can't have two or four people initiating a breath at different times; they need to be all breathing synchronously for one ventilator to deliver the breath to everyone. In the study, the sheep were paralyzed, using a neuromuscular blockade agent, with the physician setting the respiratory rate. Temporarily paralysis will most likely be a requirement for humans and is not an insurmountable problem.

The second problem is related to the stiffening of the lungs with ARDS. The increasing heaviness of the lung and loss of recoil increases resistance to delivering the necessary volumes by the ventilator. And to an extent, you compensate by increasing pressure. But with two or four patients in this ventilator "daisy-chain," less volume goes to the stiffer, more resistant lung – someone is not getting the ventilation they need. It happened with the sheep and will undoubtedly occur with humans. For this system to work, we need a way to even out that disparity.

"...lung compliance may differ so much between individuals that adequate ventilation of the least compliant patients on a circuit may not be achievable... While this is a major concern, it must be weighed against the inability of existing equipment and personnel to provide any ventilation at all to certain patients."

Finally, perhaps most importantly, there is the issue of cross-contamination. The separate path of air going to the patient have constant positive pressure, so no microbial or viral contamination would be expected from that side of the circuit. But with the exhalation, those aerosols and droplets forming in a patient's lungs are another matter. All the exhaust circuits were separated from one another, and online filters placed to trap particulates (think an inline N95 mask). No study has looked at his problem.

"As with all other issues in disaster medicine, clinicians must balance concerns about cross-contamination against the need to ration mechanical ventilation and the feasibility of other options."

Linking multiple patients to a single ventilator may work, may tide people over while waiting for their own life support, but it is not a sure thing. As multiple sources have indicated, we need more ventilators, and it appears that industry is beginning to reposition for that role. In the meantime, you can do your part, wash your hands, and social distancing. That is prevention, and it is worth more than a "pound of cure," or perhaps even an additional ventilator; it is one more life at less risk.
[1] My apologies to my instructors in respiratory physiology for presenting this abbreviated model and to my mentors for not discussing the vital role of blood flow in oxygen delivery.

[2] There is probably no better example than oxygen of the adage, that the dose makes the poison.

[3] ECMO uses a variation of the heart-lung machine, where blood is taken outside your body, oxygenated, warmed, and returned.


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Surge Capacity Mechanical Ventilation [3] Respiratory Care