Two for one with split- or co-ventilation at the peak of the COVID-19 tsunami: is there any role for communal care when the resources for personalised medicine are exhausted?

Steven Dale Pearson, Jesse B Hall, William F Parker

The international pandemic of coronavirus disease 2019 (COVID-19) has caused unprecedented strain on healthcare systems worldwide and threatens to deplete the available supply of mechanical ventilators. In addition to ventilator allocation protocols, a potential way of addressing this problem is ventilator sharing, also termed split- or co-ventilation, a concept that has gained recent attention in anticipation of dire equipment shortages. Co-ventilation was initially proposed by Neyman and Irvin in 2006 as a method of increasing surge capacity needs during disasters resulting in mass casualty respiratory failure. They demonstrated the technical feasibility of using one ventilator on four mechanical lungs, and proposed use as a last resort only after depletion of ventilators and staff available for manual ventilation to temporarily bridge to the arrival of disaster relief.[1] Similar circuits have since been used in both sheep models and more sophisticated mechanical lung models.[2 3] Tonetti and colleagues describe a simple circuit which can be used to ventilate two patients with one ventilator and report on its use in mechanical lung models of differing compliance and resistance.[4] While this report again demonstrates the technical feasibility of ventilating multiple patients with a single ventilator, there are many areas of caution to consider before widespread implementation of this technique in the current pandemic.

Tonetti and colleagues, as well as the protocol recently published by New York Presbyterian Hospital, have attempted to address many of the technical challenges of co-ventilation, although many still remain.[4 5] Front and centre among these problems is the inability to titrate mechanical ventilation to the individual patient physiology. Close matching of ventilatory settings—such as minute ventilation, positive end-expiratory pressure and fraction of inspired oxygen—to patient characteristics such as pulmonary mechanics (static compliance, resistance); oxygen consumption and carbon dioxide production; acid-base balance; and haemodynamics—is necessary to optimise the chance of survival in these severely ill patients. By way of example, the primary lung disorder manifesting in COVID-19 infection is the acute respiratory distress syndrome (ARDS), and we have learnt that lives are saved when such patients are managed with lung protective strategies including low tidal volumes. Assuring that two patients connected to a single ventilator, with different lung mechanics, would receive optimal ventilation is unlikely. This is nicely demonstrated in the current study, showing the predictable change in distribution of ventilation between the two lung models when lung compliances differ.

Even if, in a large pool of patients, initial pairs could be matched on the basis of their respiratory and metabolic parameters, the dynamic nature of these variables in critically ill patients is likely to result in divergence of these characteristics after the initial matching. An acute clinical change, ranging from a mucous plug to a metabolic acidosis, would necessitate either conversion to single patient ventilation or result in significant harm to one or both patients. As spontaneous respiratory effort from either patient must be avoided during co-ventilation, continuous neuromuscular blockade or deep sedation is required to eliminate the risk of detrimental patient–patient or patient–ventilator interactions. This would preclude performing daily interruption of sedatives and spontaneous breathing trials, interventions which have both been shown to improve patient outcomes and reduce the duration of mechanical ventilation,[6 7] and poses a challenge in assessing readiness for liberation from mechanical ventilation. Additionally, while co-ventilation may free additional ventilators, its technically challenging nature would disproportionately utilise another resource in short supply: experts in mechanical ventilation such as intensivists and respiratory therapists.

Aside from the technical challenges outlined above, there are also numerous ethical issues that arise when considering the use of co-ventilation in the current pandemic. During a severe shortage, medical ethicists agree that assignment of ventilators should move from 'first-come, first-serve' to an allocation plan that attempts to do the greatest good for the greatest number.[8 9] If co-ventilation was known to be as effective as single ventilation, the calculus would be simple. However, one could imagine the plausible scenario of two patients each having a 50% chance of survival with single ventilation and a 20% chance with co-ventilation. In this example, co-ventilating the two patients would on average be worse from a 'lives saved' standpoint compared with providing single ventilation to only one of the patients. Whether or not the benefit of providing support to one additional patient outweighs the harms suffered by the two patients receiving co-ventilation is an impossible question to answer at this point given the lack of evidence and experience, and these harms are unlikely to be amenable to rigorous quantification at any point in the near future.

Furthermore, if it is to be adopted, how should co-ventilation be incorporated into ventilator allocation algorithms? To ethically determine which patients should receive co-ventilation, algorithms will need to incorporate life saved with mechanical ventilation and harms done by co-ventilation and also patient matching characteristics; what if the two patients determined to be the best physiological match are also the most likely to benefit from individual ventilation? In the event that a patient undergoing co-ventilation requires conversion to single patient ventilation due to an acute clinical change, where would the additional ventilator be sourced from? Any ventilators not already in use dedicated to standby duty would mean additional patients not receiving mechanical ventilation. Developing the optimal ratio for shared ventilators to standby ventilators only further complicates ventilator allocation, an already contentious topic,[8 9] resulting in a utilitarian calculation that will likely prove impossible to complete in practice. Co-ventilation would be ethical, however, if the consent of the patient or surrogate was obtained. Altruistic patients and families may be willing to accept the uncertainty and increased risk of

Section of Pulmonary and Critical Care Medicine, University of Chicago, Chicago, Illinois, USA

Correspondence to Dr Jesse B Hall, Section of Pulmonary and Critical Care Medicine, University of Chicago, Chicago, IL 60615, USA; jhall@medicine.bsd.uchicago.edu

co-ventilation in order to free an additional ventilator for another patient and generate more clinical data on the effectiveness of co-ventilation.

Given the above issues, if co-ventilation is to be used, it should only be as an absolute last resort after all other available resources and options have been exhausted, as clearly stated by the authors of this report.[4] Co-ventilation should occur under a prospective protocol approved by an institutional review or ethics board. If co-ventilation is used, the process should be standardised, thoughtful and not driven by subjective decisions made at the bedside. Every effort should be made to first optimise the current supply of devices capable of supplying ventilatory support. This includes cancellation of all elective surgeries and procedures anticipated to require mechanical ventilators, permitting equipment and staff to be redirected to treating respiratory failure. Interfaces designed for non-invasive ventilation can be configured to deliver continuous or bilevel positive pressure invasively for intubated patients capable of spontaneous breathing. Additionally, the need for mechanical ventilation may be averted altogether by other respiratory support devices such as helmet ventilation with high flow oxygen alone[10] and early utilisation of palliative care services.

Whether co-ventilation should be implemented as a solution for ventilator shortages comes down to the fundamental question of whether it is best to provide optimal care to a more limited and select number of patients, or suboptimal care to a larger group. The role for co-ventilation appeals to the rule of rescue, the natural impulse to save those facing certain death, by freeing mechanical ventilators to support those in respiratory failure who would die without them. But, to use the lifeboat analogy, is taking on more passengers than the boat was designed to accommodate worth the risk of sinking the lifeboat? From a utilitarian standpoint purely attempting to maximise quality-adjusted life years, this question cannot yet be answered as the data on life years lost by co-ventilation and the exact risks it poses are unknown. We know how many passengers the lifeboat was designed to accommodate and have experience piloting it safely and effectively with that number aboard. We have now demonstrated the technical feasibility of fitting more passengers aboard the lifeboat than it was meant to service, but have no experience of piloting the boat above capacity in calm waters, much less on the stormy sea of ARDS due to COVID-19. Exactly how the lifeboat will be affected by the surplus of passengers, and at what point the boat will sink, all remain unknowns. Should an institution's supply of ventilators become depleted despite all efforts, on arrival of the next patient with respiratory failure requiring mechanical ventilation, co-ventilation may be as good an option as the alternatives, or it may be worse. Unfortunately, given the current situation facing our world and its inadequate and maldistributed healthcare resources, a forced experience with co-ventilation is likely, hopefully alongside growing experience leading to solutions which may allow it to be a safer and more viable option.[11] Even our language belies our ambiguity in sharing resources—split-ventilation implying loss, while co-ventilation suggests a willingness to help and share. Humankind should realise it has been forced into a lifeboat by this pandemic, without the luxury of yesterday's ethical postures until rescue arrives.

Contributors All authors contributed to the drafting, revision and final approval of the editorial.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Commissioned; internally peer reviewed.

To cite Pearson SD, Hall JB, Parker WF. *Thorax* 2020;**75**:444–445.

Accepted 7 April 2020
Published Online First 23 April 2020

Linked

► http://dx.doi.org/10.1136/thoraxjnl-2020-214967
► http://dx.doi.org/10.1136/thoraxjnl-2020-214895

Thorax 2020;**75**:444–445.
doi:10.1136/thoraxjnl-2020-214929

REFERENCES

1 Neyman G, Irvin CB. A single ventilator for multiple simulated patients to meet disaster surge. *Acad Emerg Med* 2006;13:1246–9.
2 Branson RD, Blakeman TC, Robinson BR, *et al*. Use of a single ventilator to support 4 patients: laboratory evaluation of a limited concept. *Respir Care* 2012;57:399–403.
3 Paladino L, Silverberg M, Charchaflieh JG, *et al*. Increasing ventilator surge capacity in disasters: ventilation of four adult-human-sized sheep on a single ventilator with a modified circuit. *Resuscitation* 2008;77:121–6.
4 Tonetti T, Zanella A, Pizzilli G, *et al*. One ventilator for two patients: feasibility and considerations of a last resort solution in case of equipment shortage. *Thorax* 2020;75:519–21.
5 Beitler JR, Kallet R, Kacmarek R, *et al*. Ventilator sharing protocol: dual-patient ventilation with a single mechanical ventilator for use during critical ventilator shortages. Available: www.gnyha.org/wp-content/uploads/2020/03/Ventilator-Sharing-Protocol-Dual-Patient-Ventilation-with-a-Single-Mechanical-Ventilator-for-Use-during-Critical-Ventilator-Shortages.pdf [Accessed Mar 2020].
6 Girard TD, Kress JP, Fuchs BD, *et al*. Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (awakening and breathing controlled trial): a randomised controlled trial. *Lancet* 2008;371:126–34.
7 Kress JP, Pohlman AS, O'Connor MF, *et al*. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. *N Engl J Med* 2000;342:1471–7.
8 Emanuel EJ, Persad G, Upshur R, *et al*. Fair allocation of scarce medical resources in the time of Covid-19. *N Engl J Med* 2020. doi:10.1056/NEJMsb2005114. [Epub ahead of print: 23 Mar 2020].
9 White DB, Lo B. A framework for rationing ventilators and critical care beds during the COVID-19 pandemic. *JAMA* 2020. doi:10.1001/jama.2020.5046. [Epub ahead of print: 27 Mar 2020].
10 Patel BK, Wolfe KS, Pohlman AS, *et al*. Effect of noninvasive ventilation delivered by helmet vs face mask on the rate of endotracheal intubation in patients with acute respiratory distress syndrome: a randomized clinical trial helmet vs face mask and endotracheal intubation in patients with ARDS helmet vs face mask and endotracheal intubation in patients with ARDS. *JAMA* 2016;315:2435–41.
11 Greensweig T. Splitting vents. Available: https://greensweig.net/splitting-vents/ [Accessed Mar 2020].

Simple ‘do it yourself’ circuit to ventilate two patients at once is technically feasible

But still not known if split ventilation pros outweigh cons so should only be used as last resort, say specialists

A simple ‘do it yourself’ breathing circuit, using accessories that are readily available in intensive care, can be used to ventilate two critically ill patients at once, should clinicians be faced with equipment shortages, suggests research published online in the journal ***Thorax***.

But although technically feasible, it isn’t clear if the pros of split ventilation outweigh the cons, and the approach is fraught with ethical issues, so this circuit should only be used as a last resort, say critical care and respiratory disease doctors in linked opinion pieces.

Prompted by the rapid rise in COVID-19 cases in the Lombardy region of Italy, and the prospect of a ventilator shortage, Italian doctors assembled and tested a simple, easily built breathing circuit on two ‘pretend’ patients.

The circuit comprised routine and readily accessible tubing and accessories found in intensive care and operating theatres.

The 15-hour tests confirmed that it would be technically feasible to use the circuit to ventilate two patients at the same time.

What’s more, the technique is safer for staff than manual bag ventilation and avoids the constant need for a ‘human ventilator’ to work the bag, so freeing up staff, say the researchers.

But the tests also showed that the level of ventilation provided wasn’t evenly distributed when lung function and capacity differed between the two ‘patients.’

It should therefore only be used as a last resort, caution the researchers, because of the need to closely match the physiology of both patients, and the impossibility of being able to monitor separately changes in each patient’s respiratory response.

There are also ethical issues to consider, they point out. “Indeed, the most difficult choice during such an emergency would be to either accept a grim triage reality (in which not all patients receive a ventilator), or accept the fact that trying to save two patients with one ventilator could mean harming at least one of them,” they write.

These concerns are picked up in a linked editorial by respiratory disease and critical care doctors from the University of Chicago.

The idea of ventilator sharing isn’t new, explain Drs Steven Pearson, Jesse Hall, and William Parker. It was first suggested in 2006, for coping with equipment shortages in dire emergencies, and has been revived in anticipation of ventilator supply problems during the COVID-19 pandemic.

But they warn that even if patients can be matched before ventilation, the dynamic nature of the respiratory response means that these initial characteristics could subsequently diverge.

Daily pauses in the sedation needed for mechanical ventilation to check on the patient’s ability to breathe unaided--which seems to help patients recover--would be extremely difficult if two people were connected to the same device, they point out.

The technical challenges also require other resources in short supply: intensivists and respiratory therapists, they say.

During a severe equipment shortage, clinical decisions would need to be based on ensuring the greatest good for the greatest number of patients, they explain. But what would happen if two patients each had a 50% chance of survival with a single ventilator, but only 20% on split ventilation, they ask?

“Whether or not the benefit of providing support to one additional patient outweighs the harms suffered by the two patients receiving co-ventilation is an impossible question to answer at this point, given the lack of evidence and experience, and these harms are unlikely to be amenable to rigorous quantification at any point in the near future,” they write.

Ideally, in the absence of adequate supply, or other breathing support devices, patient (and family) consent should be obtained and strict protocols applied for the circumstances in which split ventilation can be used, and then only as a last resort, they emphasise.

“The role for co-ventilation appeals to the rule of rescue, the natural impulse to save those facing certain death, by freeing mechanical ventilators to support those in respiratory failure who would die without them,” they write.

“But to use the lifeboat analogy, is taking on more passengers than the boat was designed to accommodate, worth the risk of sinking the lifeboat?”

Given current supply and demand, doctors will most likely be faced with such decisions, they suggest. “Humankind should realise it has been forced into a lifeboat by this pandemic without the luxury of yesterday’s ethical postures until rescue arrives,” they conclude.

In a further linked commentary, emergency care doctors in Detroit and New York agree that one patient per ventilator is best. Their YouTube video, setting out the experimental technique for ventilating four patients at the same time, inspired the Italian doctors to experiment with the approach for two patients.

“Everyone agrees one patient on one ventilator will always be the gold standard,” write Drs Charlene Babcock and Lorenzo Paladino. “Use of one ventilator for two patients is clearly outside the manufacturer’s recommendations and only appropriate in dire circumstances during a disaster.”

But reporting on further experiences of the technique can only assist the understanding of how to expand ventilator options, they suggest.

“We commend the [Italian] authors of this study for further advancing documentation of this potential expansion of ventilator availability as a life-saving intervention during a disaster and hope the additional information we have provided may be informative,” they conclude.