



## Optimizing Ventilator Use during the COVID-19 Pandemic

The COVID-19 outbreak is presenting unprecedented challenges to our health care system. According to our best projections, combined with information on the ground, the availability of precious medical resources will be limited because of the numbers of patients and their severity of illness. Among the most important resources will be mechanical ventilators, affiliated gases and disposables, and of course, qualified professionals to operate these devices.

In order to meet the growing demand, it is essential that we aggressively implement the following four overall measures:

- Rigorous adherence to all social distancing measures, including limitations on gatherings and travel. This is the best way to reduce demand.
- Guidelines to optimize the use of mechanical ventilators (Appendix A). This includes canceling elective surgeries, use of equipment from state regions not experiencing outbreaks, as well as transition of anesthesia machines and other respiratory devices for use as mechanical support for those in respiratory failure from COVID-19 and other diseases.
- Judicious, data driven requests and usage of the Strategic National Stockpile of ventilators and equipment. There are significant resources in the SNS, but all states must be data-driven in their requests based on the actual capacity for mechanical ventilation including anesthesia machine conversions. Thousands of supplemental ventilators have already been deployed around the country. In addition, the Mercy and the Comfort have deployed to the west and east coasts, respectively.
- Increasing the capacity of the SNS through federal procurement. The SNS will receive at least an additional 20,000 mechanical ventilators by mid-May.

In addition to these measures, a possible crisis standard of care strategy, currently contemplated by several centers, is the ventilation of two patients with a single mechanical ventilator. As pointed out by six organization including the Society of Critical Care Medicine and the American Society of Anesthesiologists, there are significant technical challenges that must be overcome (Appendix B); and such a strategy should only be considered as an absolute last resort, judged against the alternatives of long term “hand bagging” or death. These decisions must be made on an individual institution, care-provider, and patient level. However, we do know that many institutions are evaluating this practice, and protocols are being developed and tested, and in some places, preliminarily implemented.

Because this is a real discussion by many clinicians, the intent here is to provide additional information to support patient-provider decision making during times of crisis standards of care.

Therefore, attached are technical documents developed by academic leaders assembled at FEMA, in order to provide an example of the type of circuits, setups, and anticipated problems that one might face if this strategy is employed - in a crisis care, life-or-death, situation (Appendix C). In addition, we are attaching a protocol developed by Columbia University as an additional example for your review (Appendix D). In addition, we wanted to provide comments from the FDA and CDC related to the circuits and materials used in Appendix C.

**CDC Statement:** The infection control implications of co-venting are not firmly established, since it would not meet general established standards for infection control for ventilated patients. However, with the criteria specified and if done with currently established infection control interventions to reduce healthcare-associated infections, including ventilator associated infections, any additional risk is likely to be small and would likely be appropriate in a crisis standard of care.

**FDA Statement:** FDA does not object to the creation and use of the T-connector that meets specifications described in the instructions provided to us for use in placing more than one patient on mechanical ventilation when the number of patients who need invasive mechanical ventilation exceeds the supply of available ventilators and the usual medical standards of care has been changed to crisis care in the interest of preserving life. The FDA's no objection applies during the duration of the declared COVID-19 emergency.

During this crisis, we need to have open and transparent communication of best practices and lessons learned. We will provide updates as they become available. We stand with you, our professional colleagues, as we move forward to fully engage this crisis in our ICUs and ORs, hospitals, hospital ships, and alternative care facilities.

/S/

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/S/

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## APPENDICES

- A. Guidelines to Optimize the Use of Mechanical Ventilators
- B. Consensus Statement on the Concept of Placing Multiple Patients on a Single Mechanical Ventilator

*The Society of Critical Care Medicine, American Association for Respiratory Care,  
American Society of Anesthesiologists, Anesthesia Patient Safety Foundation,  
American Association of Critical-Care Nurses, American College of Chest Physicians*

- C. Co-ventilating Patients during a Critical Ventilator Shortage Technical Documents
- D. Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortage

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## APPENDIX A:

### Guidelines to Optimize the Use of Mechanical Ventilators



## Strategies to Optimize Provision of Mechanical Ventilation

Alternative strategies for ventilator support can and should be implemented, consistent with crisis standards of care, when resources are limited relative to the clinical demand.

1. Cancel elective surgeries and other elective procedures that could result in the use of mechanical ventilators. Transfer ventilators, supplies, and personnel from ambulatory surgery centers and other facilities not being utilized for COVID-19 patients.
2. Transfer ventilators, supplies, and personnel from areas of the state not experiencing COVID-19 outbreaks, or transfer COVID-19 patients to those areas when feasible.
3. Anesthesia ventilation machines capable of providing controlled ventilation or assisted ventilation may be used outside of the traditional use for anesthetic indication. The ASA and FDA provide specific guidance on how to convert anesthesia machines for use on COVID-19 patients in respiratory failure.
4. Transport ventilators may be used for prolonged ventilation in certain patients.
5. Continuous ventilators labeled for home use may be used in a medical facility setting depending on the features of the ventilator and provided there is appropriate monitoring (as available) of the patient's condition.
6. Noninvasive Ventilation (NIV) Patient Interfaces capable of prescribed breath may be used for patients requiring such ventilator support, including NIV Patient Interfaces labeled for sleep apnea. Channeling exhalation through a filter is recommended to prevent aerosolization.
7. Continuous Positive Airway Pressure (CPAP), auto-CPAP, and bilevel positive airway pressure (BiPAP or BPAP) machines typically used for treatment of sleep apnea (either in the home or facility setting) may be used to support patients with respiratory insufficiency. BiPAP may be used for invasive ventilation.
8. If all other alternatives are exhausted, care providers could consider ventilation of two patients on a single ventilator for short-term use, although there are significant limitations to this strategy. Alternatively, manual bag-valve-mask ventilation done by ancillary providers can be considered as a bridging option to mechanical ventilation.

APPENDIX B:

Consensus Statement on the Concept of Placing Multiple Patients on a Single Mechanical Ventilator

*The Society of Critical Care Medicine, American Association for Respiratory Care,  
American Society of Anesthesiologists, Anesthesia Patient Safety Foundation,  
American Association of Critical-Care Nurses, American College of Chest Physicians*

## Joint Statement on Multiple Patients Per Ventilator

March 26, 2020: The Society of Critical Care Medicine (SCCM), American Association for Respiratory Care (AARC), American Society of Anesthesiologists (ASA), Anesthesia Patient Safety Foundation (ASPF), American Association of Critical-Care Nurses (AACN), and American College of Chest Physicians (CHEST) issue this consensus statement on the concept of placing multiple patients on a single mechanical ventilator.

The above-named organizations advise clinicians that sharing mechanical ventilators should not be attempted because it cannot be done safely with current equipment. The physiology of patients with COVID-19-onset acute respiratory distress syndrome (ARDS) is complex. Even in ideal circumstances, ventilating a single patient with ARDS and nonhomogenous lung disease is difficult and is associated with a 40%-60% mortality rate. Attempting to ventilate multiple patients with COVID-19, given the issues described here, could lead to poor outcomes and high mortality rates for all patients cohorted. In accordance with the exceedingly difficult, but not uncommon, triage decisions often made in medical crises, it is better to purpose the ventilator to the patient most likely to benefit than fail to prevent, or even cause, the demise of multiple patients.

**Background:** The interest in ventilating multiple patients on one ventilator has been piqued by those who would like to expand access to mechanical ventilators during the COVID-19 pandemic. The first modern descriptions of multiple patients per ventilator were advanced by Neyman et al in 2006<sup>1</sup> and Paladino et al in 2013.<sup>2</sup> However, in each instance, Branson, Rubinson, and others have cautioned against the use of this technique.<sup>3-5</sup> With current equipment designed for a single patient, we recommend that clinicians do not attempt to ventilate more than one patient with a single ventilator while any clinically proven, safe, and reliable therapy remains available (ie, in a dire, temporary emergency).

Attempting to ventilate multiple patients would likely require arranging the patients in a spoke-like fashion around the ventilator as a central hub. This positioning moves the patients away from the supplies of oxygen, air, and vacuum at the head of the bed. It also places the patients in proximity to each other, allowing for transfer of organisms. Spacing the patients farther apart would likely result in hypercarbia.

Spontaneous breathing by a single patient sensed by the ventilator would set the respiratory frequency for all the other patients. The added circuit volume could preclude triggering. Patients may also share gas between circuits in the absence of one-way valves. Pendelluft between patients is possible, resulting in both cross-infection and over-distension. Setting alarms can monitor only the total response of the patients' respiratory systems as a whole. This would hide changes occurring in only one patient. The reasons for avoiding ventilating multiple patients with a single ventilator are numerous.

These reasons include:

- Volumes would go to the most compliant lung segments.
- Positive end-expiratory pressure, which is of critical importance in these patients, would be impossible to manage.
- Monitoring patients and measuring pulmonary mechanics would be challenging, if not impossible.
- Alarm monitoring and management would not be feasible.
- Individualized management for clinical improvement or deterioration would be impossible.
- In the case of a cardiac arrest, ventilation to all patients would need to be stopped to allow the change to bag ventilation without aerosolizing the virus and exposing healthcare workers. This circumstance also would alter breath delivery dynamics to the other patients.
- The added circuit volume defeats the operational self-test (the test fails). The clinician would be required to operate the ventilator without a successful test, adding to errors in the measurement.
- Additional external monitoring would be required. The ventilator monitors the average pressures and volumes.
- Even if all patients connected to a single ventilator have the same clinical features at initiation, they could deteriorate and recover at different rates, and distribution of gas to each patient would be unequal and unmonitored. The sickest patient would get the smallest tidal volume and the improving patient would get the largest tidal volume.
- The greatest risks occur with sudden deterioration of a single patient (e.g., pneumothorax, kinked endotracheal tube), with the balance of ventilation distributed to the other patients.
- Finally, there are ethical issues. If the ventilator can be lifesaving for a single individual, using it on more than one patient at a time risks life-threatening treatment failure for all of them.

## References

1. Neyman G, Irvin CB. A single ventilator for multiple simulated patients to meet disaster surge. *Acad Emerg Med*. 2006 Nov;13(11):1246-1249.
2. Paladino L, Silverberg M, Charcaflieh 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 Apr;77(1):121-126.
3. Branson RD, Rubinson L. One ventilator, multiple patients: what the data really supports. *Resuscitation*. 2008 Oct;79(1):171-172; author reply 172-173.
4. Branson RD, Rubinson L. A single ventilator for multiple simulated patients to meet disaster surge. *Acad Emerg Med*. 2006 Dec;13(12):1352-1353; author reply 1353-1354.
5. Branson RD, Blakeman TC, Robinson BR, Johannigman JA. Use of a single ventilator to support 4 patients: laboratory evaluation of a limited concept. *Respir Care*. 2012 Mar;57(3):399-403.



APPENDIX C:

Co-ventilating Patients during a Critical Ventilator Shortage Technical Documents

## Co-Ventilating Patients During a Critical Ventilator Shortage: A Method for Implementation

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### Introduction

In the COVID-19 (SARS CoV-2) Pandemic, many hospitals may be confronted with the inability to provide adequate numbers of ventilators to serve all patients requiring invasive ventilation. Using one ventilator for a single patient is the only established method to safely and reliably provide mechanical ventilation for patients with acute respiratory failure. The use of 1 ventilator to support 2 patients simultaneously (Co-Venting) is technically possible and has been tested only in controlled, experimental models using test lungs or animals for brief periods. The reliability and safety of Co-Venting in critically ill patients remains unknown. Identifying and managing the complexities of critically ill patients are among the most challenging and unpredictable aspects of Co-Venting. Therefore, the use of Co-Venting should only be considered if a hospital cannot provide clinically proven, reliable, and safe methods to manage acute respiratory failure, including manual bagging. Co-Venting should be performed for the briefest time required with rapid transition to 1:1 patient-ventilator support when additional ventilators become available.

This document provides one technical method of applying Co-Venting, necessary precautions, **guidance** for patient selection and clinical management, ventilator circuit assembly, patient grouping criteria, potential ventilator adjustments, and limitations during Co-Venting.

## **General Considerations**

Every possible effort has been made to minimize safety risks. Specifically, a technique to measure tidal volumes and plateau pressures in each patient has been described and recommended as part of the routine monitoring of these patients. A proposed workflow with different Groups will allow clinicians to optimize individualization of PEEP and FiO<sub>2</sub> requirements for each patient group. Certainly, incorporation of automated alarms and immediate feedback/monitoring of volumes and pressures is an area where further technologic development would be of great benefit in augmenting the safety of co-ventilation during crisis conditions. Finally, in the event where a patient needs to be emergently disconnected from a coventilation circuit (i.e. Cardiac arrest /CPR), a procedure is described to minimize the compromise of the other co-ventilated patient.

## **Assumptions:**

1. The number of patients who need invasive mechanical ventilation exceeds the supply of available ventilators.
2. The usual medical standards of care have been changed to crisis care in the interest of preserving life
3. The usual monitoring techniques for patient care cannot be uniformly utilized
4. Triage processes are enacted that embrace patient acuity, clinical condition(s) and comorbidity have been embraced
5. The facility is a high acuity healthcare facility familiar with advanced mechanical ventilation including prone positioning therapy and is replete with expertise in critical care medicine, respiratory therapy and related fields. The facility is supported by 24/7 critical care medicine, bedside critical care nursing, respiratory therapy, point of care testing, portable radiology, anesthesiology, and pharmacy
6. This technique is to be used while pairing COVID-19 (+) patients with one another or COVID-19 (-) patients with one another; mixing COVID-19 status patients while Co-Venting is not recommended
7. Patients need to be heavily sedated (RASS -4) to suppress their respiratory drive. If sedation is not adequate, neuromuscular blockers may be added to obliterate any respiratory effort
8. This protocol was developed exclusively for Pressure Cycled Modes of ventilation

## **Criteria:**

1. Invasive mechanical ventilation is required to manage work of breathing, hypoxia, hypercarbia or a combination of those conditions
2. The patient's clinical condition is believed to have a reasonable likelihood of salvage

## **Exclusions:**

1. Both patients have tracheostomies (creates an issue with limb clamping to determine delivered volume)
2. Lack of sufficient resources to support complex mechanical ventilation and the bedside clinical management using a geographically fixed team-based approach
3. Cessation of pandemic crisis standards of care

#### 4. Sufficient mechanical ventilators for 1:1 patient: ventilator care

### Co-Venting Procedure

Patient should be initially identified as either a PUI (Person under Investigation) or COVID +. If PUI, patient should be allocated to a single ventilator and managed accordingly. If COVID +, patient may be co-vented.

There are 3 situations when Co-venting:

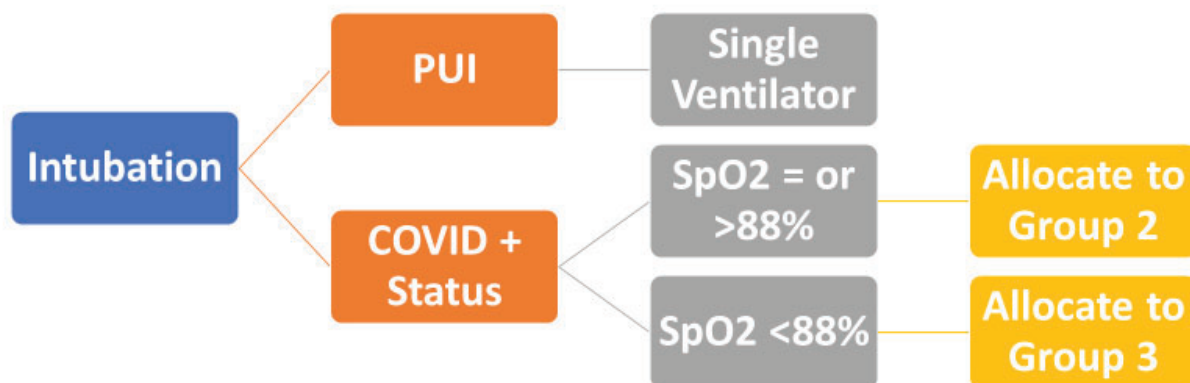
#### 1. Initial Assessment and Group Assignment of the Newly Intubated Patient

After intubation, oxygen requirements should be assessed. If SpO<sub>2</sub> is = or > 88% with usual manual bag ventilation, patient should be allocated to group 2. After 1 hour, ABG, V<sub>t</sub>, ETCO<sub>2</sub> and SpO<sub>2</sub> should be assessed to determine if the patient is appropriate to remain in Group 2.

The **estimated tidal volume** for patient A can be determined by clamping the ET tube of patient B for 3 breaths, and observe the tidal volume (TV) delivered on the ventilator to patient A (which reveals the TV to patient A), and subtract from the total volume (to both patients) to estimate the TV for patient B.

On the other hand, if SpO<sub>2</sub> is <88% with manual bag ventilation, patient should be allocated to Group 3. Parameters (ABG, V<sub>t</sub>, ETCO<sub>2</sub> and SpO<sub>2</sub>) should again be assessed after 1 hour to determine if the patient is appropriate to remain in Group 3.

## Initial Group Placement After Intubation



#### Variables to consider to assess adequacy of ventilation

- ETCO<sub>2</sub> and SpO<sub>2</sub> in each patient (Expect elevated pCO<sub>2</sub>).
- Pplat q 8 hours and Tidal Volume (V<sub>t</sub>).
- ABG q 4-6 h for first 24h then frequency per Intensivist.

#### 2. Co-Venting of Existing Ventilated Patients

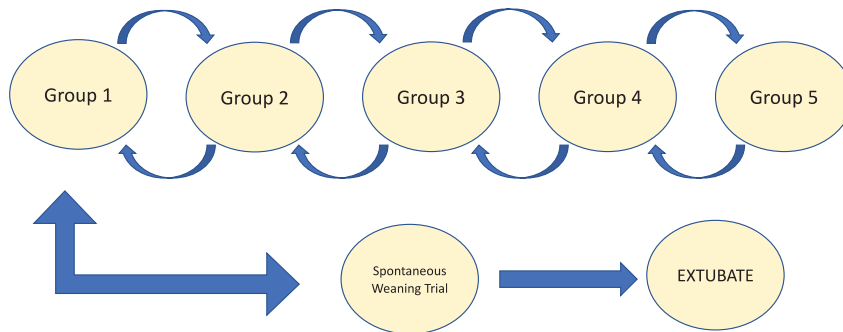
If patients are being separately vented, and there is consideration to choose 2 to be co-vented, clinicians can use the current ventilator parameters of the patients to determine who best to co-vent. Effort should be made to match compliances, minute ventilation, PEEP and O<sub>2</sub> requirements to the greatest extent possible.

### 3. Reassessment and Group Reassignment

If after 1 hour the SpO<sub>2</sub> is less 88%, patient should be reallocated to the next higher group. We accept a lower SpO<sub>2</sub> in this situation. Subsequent group changes should be prompted by changes in oxygenation and ventilation status as deemed appropriate. For Group 5 patients who continue to decompensate, Inverse Ratio Ventilation (IRV) can be considered. In a similar fashion, patients that show improvement, can be reallocated to a lower Group.

For patients in Group 2 who are thought to be ready to wean, reallocation to Group 1 can be pursued. Once stability in Group 1 has been noted for at least 1 hour then patient can be moved, ideally, to an independent ventilator for spontaneous weaning trial.

## Group Transitions



#### Considerations

- Always set ventilator to 100% FIO<sub>2</sub> when a patient is being added to a new group until further assessed (see text).
- Criteria for Transition between groups per measured parameters ( ABG, SpO<sub>2</sub>, Vt and ETCO<sub>2</sub>). See text.

## PC Settings and PEEP By Group

Group	PC	FIO <sub>2</sub>	PEEP
2	20-25	40	10
3	25-30	90	14
4	30-35	100	18
5	35-40*	100	22

Group 1: Patients deemed appropriate for weaning using 40% O<sub>2</sub>/+5 PEEP

Determine Group mobility using:  
ABG/VBG, Pplat, VT (if measurable), ETCO<sub>2</sub>, SaO<sub>2</sub>

\*Group 5 patients with persistent failure → consider IRV

## Limitations/challenges

1. Co-Venting should be considered only in COVID-19 confirmed cases. If COVID-19 status is unknown, a single ventilator should be used with only one patient connected.
2. Once COVID-19 status has been confirmed positive, begin to group COVID-19 (+) patients with similar degrees of pulmonary dysfunction (i.e. compliance).
3. Active exacerbation of asthma/COPD (i.e. wheezing/active obstructive disease) is an **ABSOLUTE CONTRAINDICATION** to be co-ventilated as it substantially complicates respiratory parameter assessment and joint patient management.
4. Expect hypercarbia with the initiation of, and perhaps throughout the process of Co-Venting. If patients are hemodynamically stable, no changes to ventilator settings may be required. If hemodynamically unstable, consider alternate options to address the impact of hypercarbia on pH, based on patient status and other existing or evolving organ failures (i.e. acute kidney injury).
5. Patient ventilatory asynchrony may occur due to an inadequately sedated patient trying to initiate a breath. This could lead to further lung injury of both Co-Vented patients. If this occurs, re-assess sedation level and consider the use of neuromuscular blocking agents in concert with sedation and analgesia to avoid the recall phenomenon.
6. Dramatic changes in ventilator settings are discouraged. However, if changes are necessary, it is prudent to change only one parameter at a time, and in only small increments (i.e. rate change by no more than 4 breaths per minute to adjust minute ventilation). Reassessment is then required as above to assess impact.
7. **Alveolar Derecruitment Prevention Procedure:** To avoid alveolar de-recruitment when breaking the ventilator circuit, use a tube clamp to temporarily occlude the proximal endotracheal tube (ETT) (avoiding clamping the ETT pilot balloon inflation line) and the wye angled adaptor (Image 2 below) to keep the circuit sealed as needed.
8. Whenever the circuit is breached (i.e. changing of heat-moisture exchanger filter (HMEF) or expiratory port filter), clamp the proximal ETT (avoiding clamping the ETT pilot balloon inflation line) to avoid aerosolization and potential pathogen spread. This procedure is analogous to the alveolar derecruitment prevention procedure above.
9. If tidal volumes suddenly or unexpectedly drop, consider a HMEF malfunction (i.e. condensation/sputum/ etc. in the HMEF); follow the above alveolar derecruitment prevention procedure, replace the HMEF and reassess.
10. If using off the shelf (i.e. Hardware store) parts, ensure that they are appropriately cleaned/decontaminated prior to inclusion in a patient circuit.
11. We discourage attempting to wean patients while they are being Co-Vented. Instead, patients suitable for weaning are recommended to be managed on a dedicated ventilator.
12. If one of the Co-Vented patients suffers cardiac arrest and the circuit must be separated, consider the following options to optimize safety:
  - a. Disconnect the arrested patient from the circuit to manually bag during the cardiac arrest. Occlude the ETT port of the circuit by using the elbow and cap included with wye connector that comes with standard ventilator circuit. (NOTE: Consider taping the wye angled adaptor and cap to either the ventilator or ventilator circuit so that it is readily visible and available in case of emergency).

Also, prior to removing the arrested patient from the circuit, follow the alveolar derecruitment prevention procedure detailed above for the non-arresting patient prior to depressurizing the system.

- b. Disconnect the T-tube splitter at the expiratory and inspiratory port and quickly convert to a single ventilator circuit to support the non-cardiac arrested patient. NOTE: use a temporary tube clamp for the non-arrested patient ETT during transition to a dedicated ventilator circuit to avoid alveolar de-recruitment.
13. In situations where a Co-Vented patient must be disconnected for procedures (i.e. CT scan etc.), use the elbow and cap procedure as described above to avoid de-recruitment of the other patient.
14. If proning is considered for Co-Vented patients, it should be done by those skilled in prone positioning. Prone position therapy is recommended only for patients meeting the Berlin criteria for severe ARDS. Challenges and potential issues that may occur while using prone positioning therapy for COVID-19(+) Co-Vented patients include but are not limited to:
  - a. An increased risk of aerosolization if the ventilator circuit becomes disconnected during the proning process
  - b. The number of personnel required to participate in prone positioning will increase the number of personnel with potential exposure
  - c. Co-Vented patients should be sequentially proned to allow reassessment of hemodynamics and ventilator dynamics that may not be predictable; do not attempt to prone patients at the same time
  - d. Both patients require reassessment after one patient is proned, not just the patient who is in the prone position
  - e. The use of a specialty bed for prone positioning is discouraged due to the potential risk of iatrogenic harm to the other Co-Vented patient.
15. Ethical and legal considerations:
  - a. The use of one ventilator for 2 patients (i.e. co-venting) has substantial ethical and legal implications. Please refer to your hospital disaster protocol and or the National disaster plan regarding the specific approach your facility recommends. Specific concerns include:
    - i. Off label use
    - ii. Use in Disaster situations
16. Room placement of a ventilator used for Co-Venting
  - a. Many ICU rooms may be too small to accommodate two patients at the same time. It is recommended to place beds side by side with the ventilator positioned at the head of the beds or between the beds.
  - b. If a larger space is available, a head-to-head configuration is ideal to facilitate axial repositioning of patients and care devices.
17. Appropriate labeling of equipment that is to be used for patient care in order to distinguish connections to Patient A compared to Patient B is ***critical***. This includes the patient, IV pumps and tubing, physiologic monitors, ventilator circuits, drains, chest tubes, etc. Consider a color-coding system or similar approach to be certain of which device connects to which patient to avoid iatrogenic harm.

## **Respiratory Therapy Guide to Co-Ventilation**

This document highlights key points for the Respiratory Therapist's role in placing 2 adult patients in a co-venting or ventilator sharing system.

FOR PURPOSES OF CLAIRITY, PATIENT B IS ASSUMED TO BE THE PATIENT ADDED OR REMOVED FROM THE CIRCUIT.

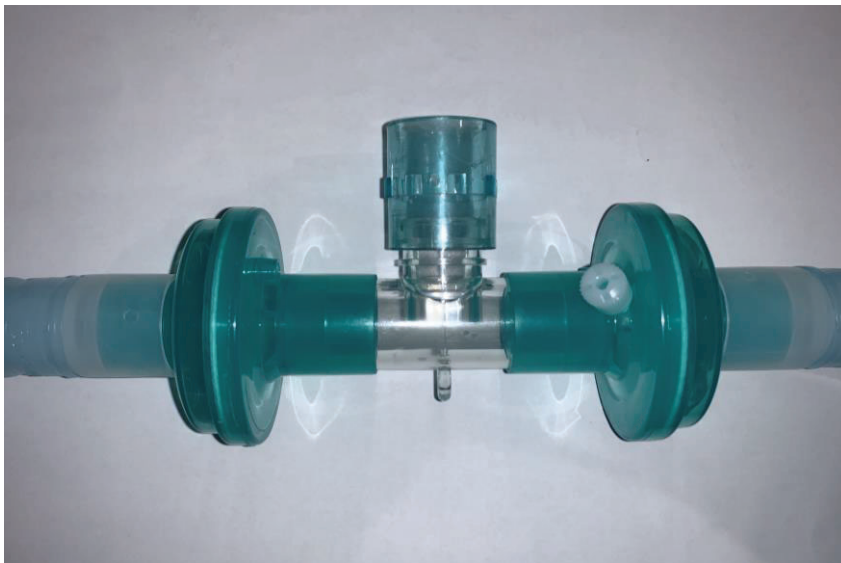
**CAUTION: IN THE EVENT OF AN EMERGENCY WHERE PATIENT B HAS TO BE REMOVED FROM THE SYSTEM, PATIENT A'S ET TUBE MUST BE CLAMPED (PER ALVEOLAR DERECUITMENT PREVENTION PROCEDURE) AND THE VENTILATOR CIRCUIT FROM PATIENT B MUST BE SEALED TO MAINTAIN PEEP AND VENTILATION FOR PATIENT A. USE THE WYE ANGLED ADAPTER AND CAP THAT COVERS THE WYE (COMES WITH THE VENILATION CIRCUIT) TO CLOSE THE VENTILATOR CIRCUIT TO PATIENT B.**

- **Supplies to be available in room before intubation**
  - Tube Clamps (one for each patient) and Terminal ET connection cap (tape to vent)
  - Ventilator
  - Elbow adaptor with cap from standard ventilator tubing circuit (tape to vent)
  - 2 vent splitters (one for inspiratory and one for expiratory circuits)
  - BVM: Bag Valve Manual resuscitator bag with mask, bacterial/viral filter and minimum 10 cmH<sub>2</sub>O PEEP valve (Ideally place another bacterial / viral filter between BVM expiratory port and PEEP valve.)
  - Heat Moisture Exchanger Filter (HMEF) Before ETT
  - 2 bacterial/viral filters at T piece of expiration port.
  - SpO<sub>2</sub> probe/monitor
  - In-line suction catheter
  - Intubation Equipment (if not already intubated)
    - GlideScope (preferred for decreased infection exposure)/ Laryngoscope
    - Stylet
    - ET tubes of different sizes
    - 10 ml Syringe to inflate ETT cuff
    - Suction equipment
    - Functioning oxygen flow meter for BVM
    - ETT facial securement device (or tape)
  
- **Ventilator Set-up**
  - End-tidal CO<sub>2</sub> monitor (if available)
  - Set ventilator in a pressure-oriented mode (i.e. Pressure Control Ventilation)
  - Trigger sensitivities (either pressure or flow) should be set as high as allowed by the ventilator ("locked - out") to minimize risk of patient-to-patient ventilator interactions
  - If creating a new group, request settings from the managing clinician
  - If adding to an existing patient:
    - Temporarily set FiO<sub>2</sub> to 100% when a patient is being added



- Ensure ET tube of existing patient is clamped to prevent de-recruitment when the system depressurizes as the new patient is added
  - Allow the system to re-pressurize 3 breaths prior to unclamping ET tubes
  - Set FiO<sub>2</sub> to level requested by clinician
- **Tidal Volume Monitoring**
  - Measure at minimum every 4 hours for each patient. Necessity of more frequent checks must be balanced with healthcare worker exposure risk
  - Procedure
    - Record Vt while both patients are being ventilated at baseline (Initial Vt)
    - Using a Tube Clamp, clamp the ET tube of patient A
    - Allow ventilator to deliver 3 breaths. Vt measured will be the estimated patient B Vt.
    - Unclamp patient A
    - Subtract patient's B Vt from initial Vt to obtain Vt of patient A. (Initial Vt – patient B Vt = patient A Vt)
- **Ventilator Goals**
  - Only make adjustments to one parameter at a time and reassess
  - If SpO<sub>2</sub> <88%, alert clinician for possible transition to a higher group
  - Expect and allow hypercarbia
- **Items of Note**
  - Ventilator may autocycle with suctioning
  - Check heat/moisture exchanger (HME) for blockage if there is a sudden drop in Vt
  - Check connections frequently and with every ventilator check

## Co-venting 2 Patients With 1 Vent Supply List



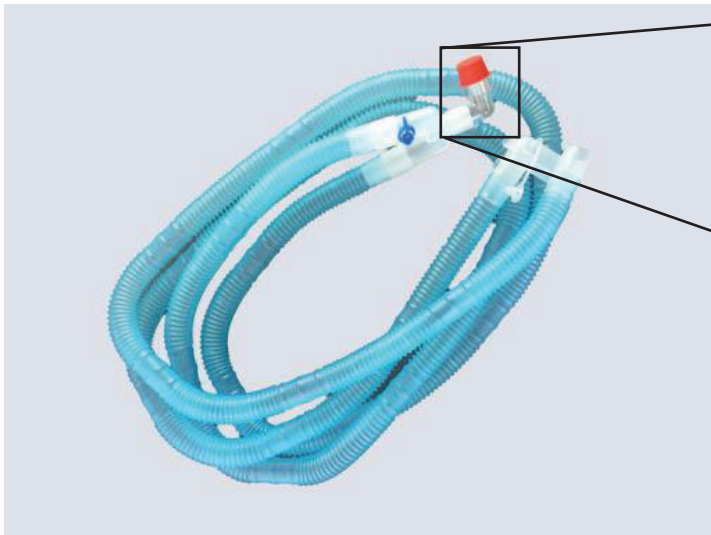
Overview and Testing: <https://youtu.be/SKh-QHMAKhc>

- 2 Plastic Tube Clamps (Image 1)

- 2 Standard Ventilation circuits. Each circuit should include (Image 2)
  - 6 feet Inspiratory corrugated tubing
  - 6 feet Expiratory corrugated tubing
  - 1 wye adaptor
  - 1 capped angled wye adaptor (tape to vent to prevent loss)
- 3 bacterial filter (Image 3)
- 2 heat moisture exchange/filter (HMEF) (Image 4)
- 2 inline suction catheters (Image 5)
- Tee connector Options
  - Option 1 (hospital sourced- Preferred )
    - 2 Tee adaptors cut from Aerosol Drainage Bag (Image 6)
    - 2 Female to Female adapter (in order of preference)
      - 22 mm adaptor (Image 7)
      - Short corrugated tube from small volume jet nebulizer setup (Image 8)
      - Cut piece of standard large bore tubing (Image 9)
  - Option 2 (community sourced – if insufficient hospital supply )
    - 2 CPVC CTS  $\frac{3}{4}$  inch Tee (Image 10)
      - CTS= Copper Tube Size (ASTM D2846)
    - 6 male to male adaptors
      - Hospital sourced 15 mm adapters (Image 11)
      - $\frac{3}{4}$  CPVC CTS pipe cut to 4 cm (Image 12)
        - CTS= Copper Tube Size



IMAGE 1- Plastic Tube Clamp



Retain this wye angled adaptor and tape to vent to occlude circuit in case of emergency

IMAGE 2 – Standard Ventilator Circuit



IMAGE 3 – Bacterial Filter



IMAGE 4 - Heat moisture exchange/filter (HMEF)



IMAGE 5 – Suction Inline Catheters

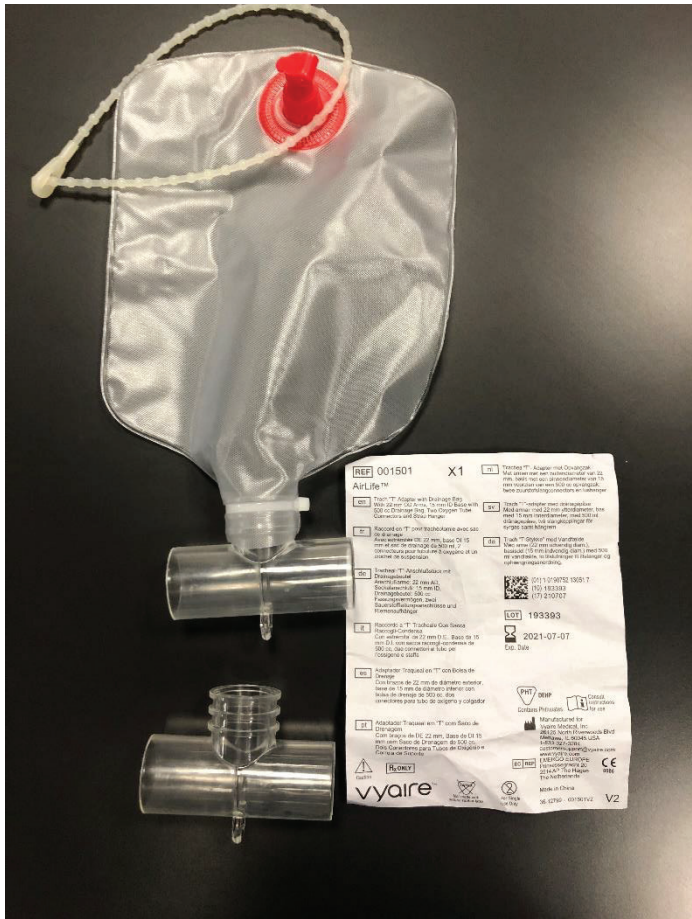


IMAGE 6 – Tee Connector cut from Aerosol Drainage Bag

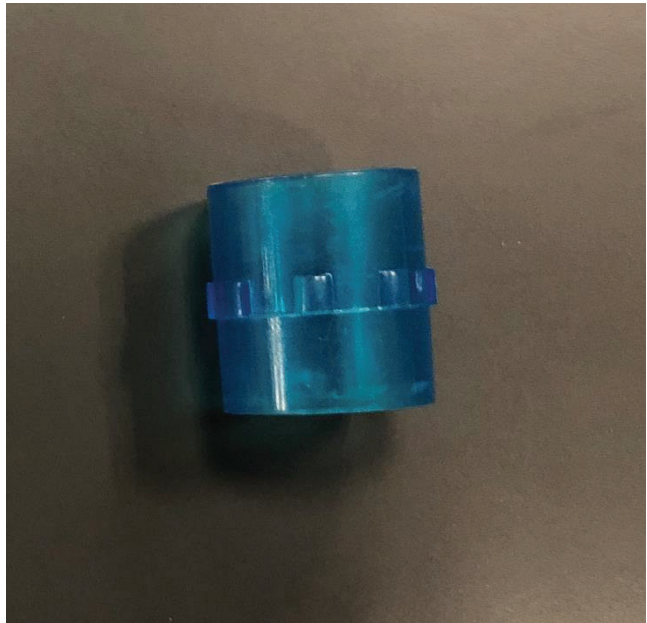


IMAGE 7 – 22 mm Adaptor

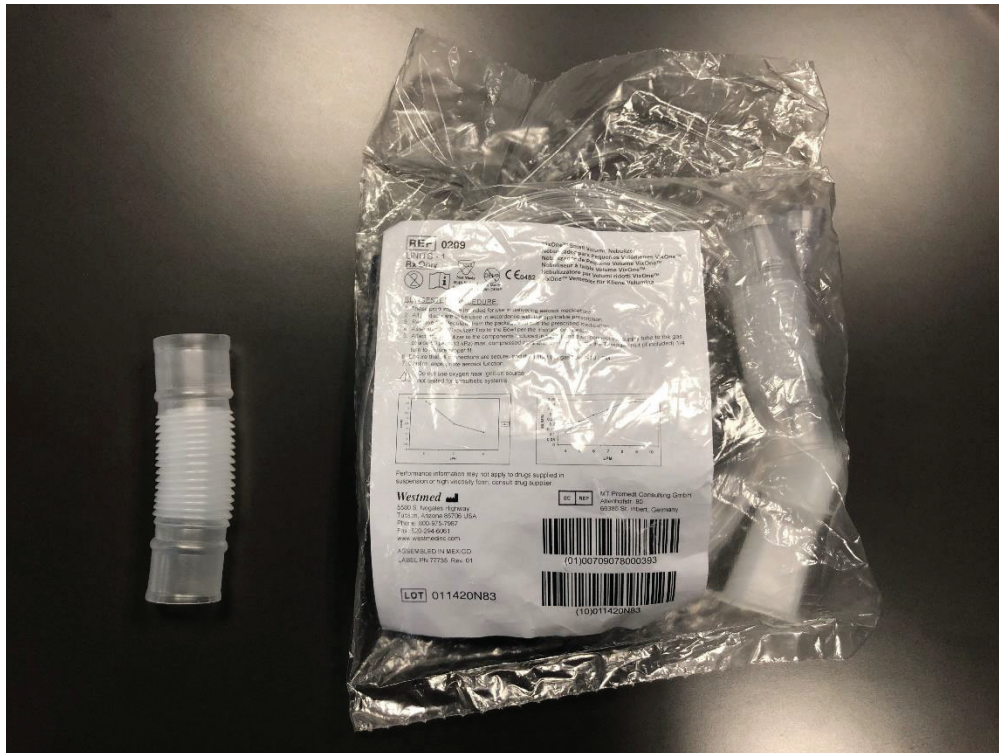


IMAGE 8 - Short corrugated tube from small volume jet nebulizer



IMAGE 9 - Cut piece of standard large bore tubing



IMAGE 10 – CPVC 3/4 inch Tee



IMAGE 11 - Hospital sourced 15 mm adapters



IMAGE 12 -  $\frac{3}{4}$  CPVC pipe cut to 4 cm

### **Training and Resources**

FAQs: (FEMA link). We hope to have this up soon

Video tutorial: available here. [https://youtu.be/TNvQb2uFe\\_Y](https://youtu.be/TNvQb2uFe_Y)

24-hr. telephone support for implementation guidance is expected soon.

Database for tracking clinical experience: follow link to portal to enter patient information (FEMA portal)

### **Conclusion**

In light of the ongoing Covid -19 pandemic, the need for mechanical ventilators across the United States may exceed our current supply. In this situation it is incumbent on medical providers and governing bodies to explore and support new strategies to provide the best possible care. This document provides a way to modify a single ventilator for off label use to co-ventilate 2 patients and provides details an initial implementation of a co-ventilation system. As this is a unique use of mechanical ventilation during a pandemic crisis, sharing feedback of implementation experiences, limitations and challenges is strongly encouraged. Please follow the link to the FEMA portal to share experience.





APPENDIX D:

Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortage

*Columbia University Vagelos College of Physicians & Surgeons  
New York-Presbyterian Hospital*

# Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortages

**Version Date:** March 27, 2020, 8:23AM (version 4)

Columbia University Vagelos College of Physicians & Surgeons  
NewYork-Presbyterian Hospital

## **Working Protocol – Subject to Revision**

*This working protocol is subject to revision. It is expected this document will be updated and re-released as additional experience is accumulated.*

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***A copy of this protocol should be available at bedside at all times for any patients undergoing the shared ventilator strategy.***

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## A. SUMMARY OF KEY PROTOCOL RISKS & SAFETY FEATURES

Supporting two patients with a single ventilator poses real risks to patients, including the following:

1. *One patient causing accidental extubation in the other.* This risk is mitigated by neuromuscular blockade. Any extubation or tube dislodgement causing air leak would be detected by PEEP alarm immediately, even during ventilator sharing.
2. *One patient infecting the other.* This risk is mitigated by antimicrobial filters and matching for respiratory pathogen.
3. *Delayed detection of hypo/hyperventilation.* This risk is mitigated by rigorous safety check before initiation, careful selection of patients with similar mechanical support needs for pairing, use of patient-specific capnography and tidal volume measures, and frequent blood gases.
4. *Detrimental patient-ventilator interactions from respiratory muscle effort (breathing, hiccup, cough).* This risk is mitigated by use of neuromuscular blockade.
5. *Delayed weaning.* This risk is mitigated by the ventilator allocation schema, reserving some ventilators for weaning.

This protocol was developed with focus on ensuring that events in one patient will not harm the other, with several safety features to that end:

1. *Neuromuscular blockade (paralysis)* ensures neither patient triggers the ventilator and helps mitigate risk of pendelluft between patients.
2. *Pressure-control mode* ensures that if airway blockage, endotracheal tube obstruction, pneumothorax, or other acute change occurs in one patient, the other patient will continue to receive the same tidal ventilatory support because driving pressure is unchanged. In contrast, with volume-control, if one patient experiences any of the above acute changes, the unaffected patient would receive a much higher tidal volume and/or the peak inspiratory pressure limit would be exceeded, canceling the inspiratory cycle & risking hypoventilation.
3. *Pressure-control mode* also ensures that if one patient occultly makes spontaneous inspiratory efforts despite paralysis, the patient effort does not “steal” tidal volume from the other patient as would occur in volume-control.
4. *Similar mechanical support needs* for patients considering to be paired together to minimize risk of deleterious ventilation-induced lung injury or hypo/hyperventilation.
5. *Ventilator alarms* are tightly adjusted to detect changes that would warrant bedside evaluation.
6. *Independent patient-specific monitoring and alarms* for tidal volume, minute-volume, end-tidal carbon dioxide, airway pressure, and airflow ensure the same individual patient information is available as during single-patient ventilation.
7. *Redundant safety checks* throughout the protocol ensure any error in key steps is identified and corrected before proceeding.
8. *Ventilator sharing is restricted to two patients on one ventilator* to minimize risk of harm to either patient. Ventilator titration to ensure appropriate full support already is challenging with two patients and would become prohibitive with additional patients sharing one ventilator. Adding more patients markedly decreases likelihood of good matching and increases likelihood that at least one patient’s course will diverge from others, creating a barrier to sharing. Technical complexity for trouble-shooting during acute events further compromises safety. These factors collectively necessitate no more than two patients for ventilator sharing in severe acute respiratory failure to ensure safety.
9. *Multiple antimicrobial filters and patient matching by respiratory pathogen* minimize risk of one patient infecting the other.

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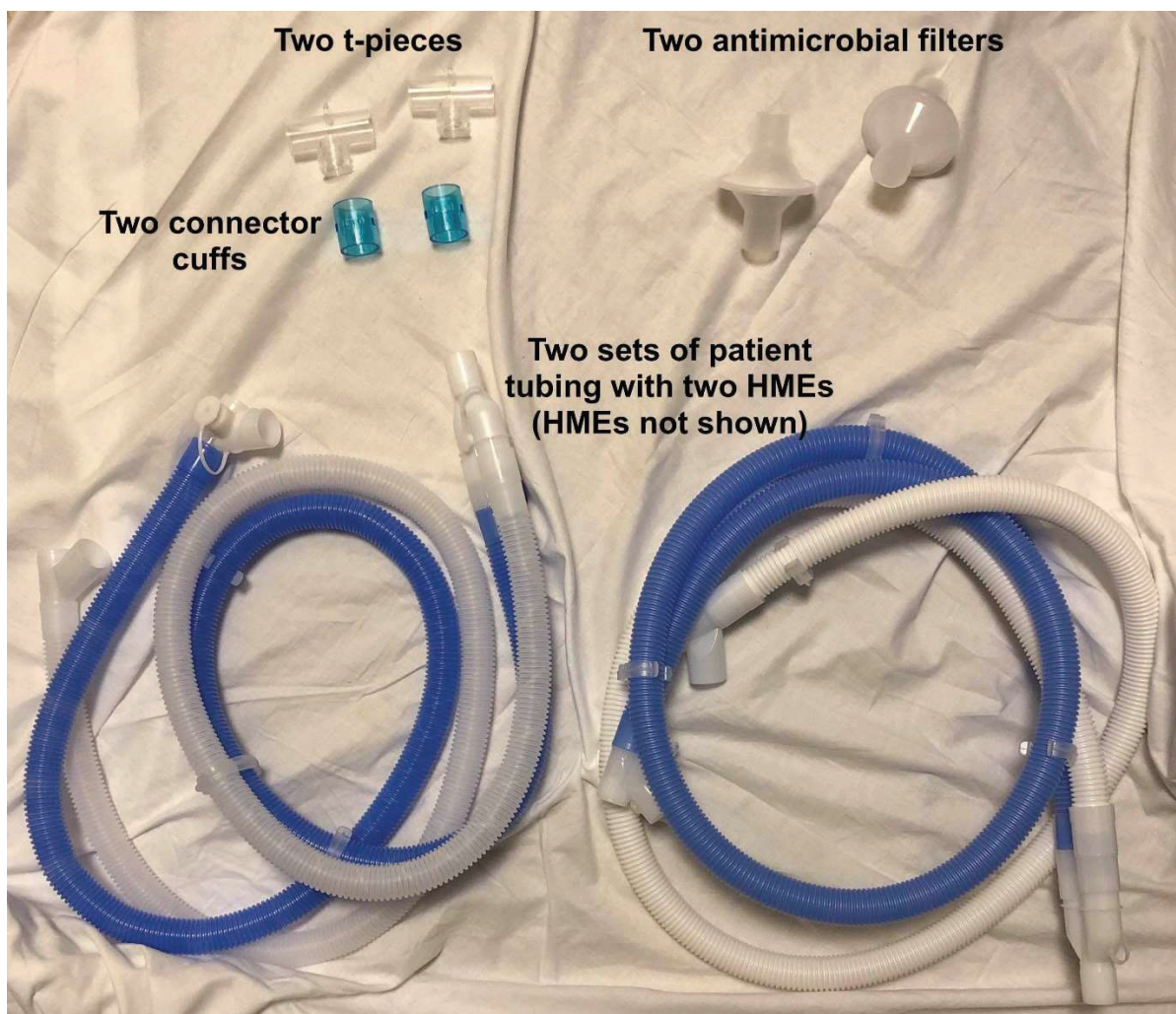
## B. EQUIPMENT & SUPPLIES

Specific equipment required may vary depending on supplies and equipment available.

1. One ventilator
2. Two sets of patient tubing
3. Two heat and moisture exchangers (HMEs)
4. Two t-pieces (often used for “t-piece” spontaneous breathing trials)
5. Two connector cuffs
6. Two antimicrobial filters

**NOTE: HEMF** (HME + antimicrobial filter in one device) **is recommended** if available. If you have an HMEF, then separate antimicrobial filters are not essential but may be considered for redundancy as hospital supplies allow. If using an HMEF, simply connect one HMEF at the endotracheal tube of each patient as you normally would.

Picture of equipment needed:



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### C. SETTING UP SHARED VENTILATOR

**\*\*\*IMPORTANT:** Setup should be done ONLY on a ventilator NOT currently supporting a patient.

**Step 1:** Connect connector cuff to bottom of T-piece



**Step 2:** Connect antimicrobial filter to one side of T-piece.\*

\*Note: If you plan to use an HMEF (HME + antimicrobial filter in one device), then separate antimicrobial filters are unnecessary and you may skip this step.

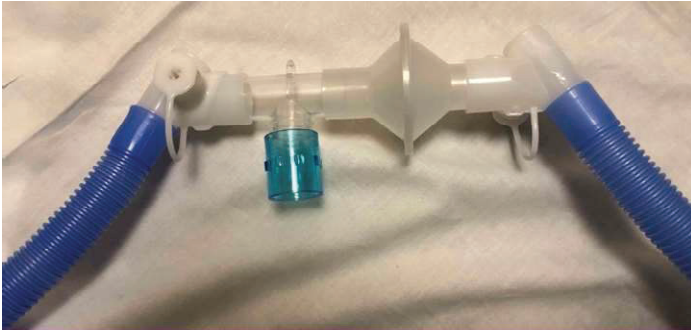


**Step 3:** Connect both expiratory limb tubes (white) to either site of one T-piece. **The expiratory limbs for both circuits MUST be connected to the same T-piece.**



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**Step 4:** Connect both inspiratory limb tubes (blue) to either side of the other T-piece. **The inspiratory limbs for both circuits MUST be connected to the same T-piece.**



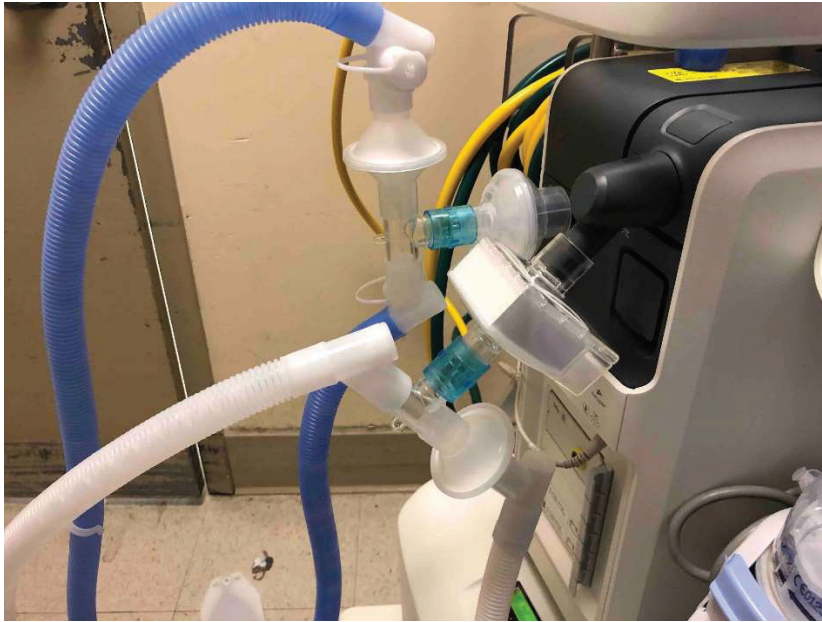
**Step 5:** Connect T-piece with inspiratory limb (blue tubing) to inspiratory port on ventilator.



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**Step 6:** Connect T-piece with expiratory limb (white tubing) to expiratory port on ventilator. Do **NOT** use the external Fisher-Paykel heater, which cannot support 2 circuits.



**Step 7:** Place HME or HMEF inline near endotracheal tube for each patient as normally done.

**Step 8:** Turn on ventilator and set alarms as recommended prior to initiating ventilator sharing.

**NOTE:** If you have an HMEF (HME + antimicrobial filter in one), then connect it near the endotracheal tube as you normally would, and separate antimicrobial filters are unnecessary.

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## D. VENTILATOR CIRCUIT SAFETY TEST

**Step 1:** Turn on new ventilator to be used for ventilator sharing. Run the system checks as you normally would per local institutional practice

*Note:* If the system check is performed with two circuits connected to the ventilator (dual-patient setup), many ventilators give an error. If such error occurs during leak test, double-check all connections to ensure they are snug. Consider repeating leak test with a single circuit attached as done in usual practice. All ventilators we tested work fine to support two patients despite this anticipated warning during the test, although the tidal volume may be misestimated by 50-80 mL. Use of independent tidal volume monitoring overcomes this issue.

**Step 2:** Connect a “test lung” to each circuit where the endotracheal tube would normally attach. The two test lungs should have identical mechanics (e.g. same manufacturer and model).

**Step 3:** Initiate ventilation in **pressure control mode** with standard settings for this mode.

**Step 4: SAFETY CHECK:** Observe the following.

1. No ventilator alarms or errors occur.
2. Both test lungs inflate and deflate at the same time with each tidal breath.
3. **Independently measure tidal volume in each test lung simultaneously to confirm they are similar**, using a respiratory monitor with inline flow measurement (e.g. Philips NM3). Note the combined tidal volume for test lung A+B. The combined tidal volume for A+B should be similar to the tidal volume on the ventilator; in our experience, they may differ by 50-80 mL due to measurement and calibration imprecision across devices.

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## E. INITIAL PATIENT COMPATIBILITY ASSESSMENT

Recommended initial requirements for identifying patients to pair together are presented in **Table 1**. Values were selected to mitigate risk to either patient and allow room for ventilator titration if needed.

<b>Table 1: Recommended initial patient compatibility criteria.</b> If patients do not meet all of these criteria, pairing them on a single ventilator is not recommended.		
<b>Parameter</b>	<b>Acceptable Limit in Either Patient</b>	<b>Acceptable Difference Between Patients (patient A – patient B)</b>
Anticipated time needing invasive ventilation	72 hours or higher	
Tidal volume	6-8 mL/kg PBW	
Driving pressure ( $\Delta P$ = plateau pressure – PEEP)	5-16 cmH <sub>2</sub> O	0-6 cmH <sub>2</sub> O
Respiratory rate	12-30 breaths/min	0-8 breaths/min
PEEP	5-18 cmH <sub>2</sub> O	0-5 cmH <sub>2</sub> O
FiO <sub>2</sub>	21-60%	
pH	7.30 or higher	
Oxygen saturation	92-100%	
Ventilator titration	No recent major changes as judged clinically	
Neuromuscular blockade	No contraindication to initiation if not already receiving	
Respiratory infectious status	Both patients have same infectious organism	None
Asthma or COPD	No severe baseline disease nor current exacerbation	
Hemodynamic stability	No rapid vasopressor increase	
<i>Abbreviations:</i> PBW = predicted body weight, calculated as follows: PBW males = 50 + 2.3 [height (inches) – 60] PBW females = 45.5 + 2.3 [height (inches) – 60]		

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## F. STEPWISE APPROACH TO MATCHING VENTILATOR SETTINGS

**Step 1:** In **both** patients: Respiratory effort must be completely eliminated as follows.

1. Titrate sedation to RASS -5 (unresponsive)
2. Initiate continuous neuromuscular blockade (paralysis) with **Cisatracurium 15mg bolus followed by continuous infusion of 37.5 mg/hour (typically 6-8 mcg/kg/min)** (Papazian et al NEJM 2010)..
  - a. **Do NOT check train of four (TOF)**. Goal is to minimize unnecessary entry into room, and TOF is irrelevant to protocol where explicit goal is to ensure passive ventilation.
3. Reconfirm initial patient compatibility in Table 1

**Step 2:** In **patient A**:

1. Make note of the following baseline values:
  - a. baseline driving pressure ( $\Delta P = \text{plateau pressure} - \text{PEEP}$ )
  - b. baseline tidal volume
  - c. baseline respiratory rate
2. Initiate **pressure control ventilation (PCV)** mode with:
  - a. **Driving pressure** (inspiratory pressure above PEEP): set to match measured baseline driving pressure.
  - b. **Inspiratory time**: adjust between 0.6 to 1.0 seconds to achieve tidal volume approximating baseline
  - c. **Respiratory rate, PEEP, and FiO<sub>2</sub>**: Unchanged from baseline unless adjustment needed for safety

**Step 3:** In **patient B**:

1. Make note of the following baseline values:
  - a. baseline driving pressure ( $\Delta P = \text{plateau pressure} - \text{PEEP}$ )
  - b. baseline tidal volume
  - c. baseline respiratory rate
2. Initiate **pressure control ventilation (PCV)** mode with:
  - a. **Driving pressure** (inspiratory pressure above PEEP): set to match measured baseline driving pressure.
  - b. **Inspiratory time**: adjust between 0.6 to 1.0 seconds to achieve tidal volume near baseline
  - c. **Respiratory rate, PEEP, and FiO<sub>2</sub>**: Unchanged from baseline unless change needed for safety

**Step 4:** In **both** patients:

1. **PEEP**: titrate to be the same in both patients.
  - a. Use clinical judgement on the appropriate PEEP that both patients can tolerate.
  - b. Consider initial PEEP adjustment set to average of the two patients.
2. **FiO<sub>2</sub>**: titrate to be the same in both patients while maintaining SpO<sub>2</sub>  $\geq$  95%.
3. **SAFETY CHECK**: Confirm **tidal volume** has **not decreased more than 50 mL after PEEP change**.
  - a. Tidal volume decrease by more than 50 mL strongly suggests either overdistension (if PEEP was increased in patient) or de-recruitment (if PEEP was decreased in patient).

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**Step 5:** In **both** patients:

1. **Driving pressure:** titrate to be the same in both patients.
  - a. Consider initial driving pressure adjustment set to average of the two patients.
2. **Inspiratory time:** titrate to be the same in both patients.
  - a. Consider initial inspiratory time adjustment set to average of the two patients.
3. **Respiratory rate:** titrate to be the same in both patients.
4. **SAFETY CHECK**
  - a. Confirm **minute-volume** remains **within  $\pm 2$  liters/min baseline in each patient**.
  - b. After 20 minutes, check **arterial or venous blood gas** in both patients to confirm pH & pCO<sub>2</sub> in acceptable range.
  - c. Confirm both patients remain **paralyzed** and not making any spontaneous breathing effort.
  - d. Confirm both patients now are tolerating **identical ventilator settings**.
  - e. Note these values for use in setting initial ventilator alarms (Table 2)

## G. RECOMMENDED INITIAL VENTILATOR ALARM SETTINGS

Parameter	Lower Alarm	Upper Alarm
Tidal volume ( $V_T$ ) <sup>a</sup>	( $V_T$ in patients A+B) – 100 mL	250 mL above minimum alarm
Respiratory rate	5 breaths/min below preset value	5 breaths/min above preset value
Peak pressure	5 cmH <sub>2</sub> O below preset value (preset = driving pressure + PEEP)	5 cmH <sub>2</sub> O above preset value (preset = driving pressure + PEEP)
PEEP	2 cmH <sub>2</sub> O below preset value	5 cmH <sub>2</sub> O above preset value
Minute-volume <sup>a</sup>	(minvol in patients A+B) – 1 liter/min	(minvol in patients A+B) + 1 liter/min

<sup>a</sup> Values for  $V_T$  and minvol are to be taken on identical ventilator settings at final safety check while both patients are still on their own ventilator just prior to pairing on one ventilator (page 6, Step 5).

**\*\*\*IMPORTANT:** During ventilator sharing, ventilator may misestimate compressible gas volume in circuit. As a result,  $V_T$  may be incorrect by ~80 mL, with similar misestimation of minute-volume.  $V_T$  alarm may need to be adjusted, but then blood gas must be done to confirm adequate ventilation.

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## H. INITIATING VENTILATOR SHARING

**\*\*\*IMPORTANT:** Disconnecting ventilator circuit is an **aerosol-generating procedure**. Anyone present should wear appropriate PPE, including eye protection and an N95 or equivalent respirator.

**Step 1:** In ***both*** patients:

1. **Increase FiO<sub>2</sub> to 100%** for preoxygenation prior to transfer.
2. Position patients sufficiently close to each other so that they can be connected to same ventilator **with NO addition of deadspace extension tubing**.

**Step 2:** Review and confirm:

1. Ventilator settings for each patient are identical while on pressure-control mode.
2. Patient compatibility assessment:
  - a. **Minute-volume** remains **within  $\pm 2$  liters/min baseline in each patient**.
  - b. **pH & pCO<sub>2</sub>** on matched ventilator settings is in acceptable range.
  - c. Both patients remain **paralyzed** and not making any spontaneous breathing effort.
3. Shared ventilator circuit is powered on, operational and insufflates both test lungs per **Section D**.

**Step 4:** Set initial ventilator settings on the new ventilator to match what both patients already are receiving. The patients already should be receiving identical ventilator settings per protocol.

**Step 5:** Complete following procedures to transition the patients to the new circuit:

1. Remove one test lung from one circuit of the new shared ventilator and cap that circuit.
2. Remove the other test lung from the shared ventilator circuit.
3. Transfer Patient A in following steps in ***immediate*** succession:
  - a. **Clamp endotracheal tube** of Patient A (minimizes aerosols and derecruitment).
  - b. Disconnect Patient A from old (single-patient) ventilator circuit.
  - c. Connect Patient A to new circuit.
  - d. **Immediately unclamp endotracheal tube after patient on new circuit**.
4. Repeat for Patient B, connecting to the other circuit on the shared ventilator.

**Step 6: SAFETY CHECK** after initiating ventilator sharing:

1. **Patient-specific tidal volume** is within  $\pm 50$  mL of tidal volumes just prior to shared ventilation.
2. **SpO<sub>2</sub> > 95%** in each patient. Wean FiO<sub>2</sub> as tolerated.
3. After 20 minutes, check **arterial or venous blood gas** in both patients to confirm pH & pCO<sub>2</sub> in acceptable range.
4. Both patients remain **paralyzed** and not making any spontaneous breathing effort.
5. Maintain old ventilators at bedside until 20-minute blood gas results returned and deemed acceptable.

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## I. MONITORING & SUPPORT DURING VENTILATOR SHARING

Recommended clinical monitoring includes:

1. Ventilator alarms carefully set (Table 2)
2. Continuous neuromuscular blockade (paralysis) for duration of time that patients are paired
3. Continuous pulse-oximetry for both patients
4. Continuous telemetry for both patients
5. Frequent blood pressure check for both patients, either continuous (preferred) or otherwise checked every 5-15 minutes
6. **End-tidal CO<sub>2</sub>** for both patients (if available)
7. **pH and pCO<sub>2</sub>** via arterial or venous blood gas in both patients **at 2 hours, 4 hours, and then q8 hours**
8. **pH and pCO<sub>2</sub>** via arterial or venous blood gas **20 minutes after every change** in ventilator support except FiO<sub>2</sub>.
9. **Independent tidal volume monitoring:** Freestanding respiratory monitors to independently monitor each patient's individual tidal volume and minute-volume are strongly advised for safety and mandatory for our institutional protocol. For example, we use the Philips NICO, NICO2, or NM3 monitor for this purpose during ventilator-sharing, which includes an inline flow sensor that can be used to track tidal volume and minute-volume.

**\*\*\*IMPORTANT:** Ventilator-reported "tidal volume" and "minute-volume" reflect additive value for both patients combined. What each individual patient is receiving is unknown. Therefore, capnography or blood gases are essential to ensure both patients have adequate ventilation.

## J. CARING FOR PATIENTS ON SHARED VENTILATOR

1. **Managing shift changes:** Each time staff changes for patients undergoing ventilator sharing, the team should huddle to review key safety elements, detailed in **Appendix 1**.
2. **Culture results and infection considerations:** Despite use of antibacterial/antiviral filters, there is no guarantee they are universally protective. Therefore, **all respiratory and blood culture results from one patient should be viewed as potentially applying to both patients**.
3. **Routine care procedures:** Any procedure that could contribute to respiratory compromise in one patient should not be done in both patients simultaneously. Such procedures include but are not limited to the following: suctioning, patient repositioning, endotracheal tube repositioning, or upper body central venous catheter insertion.

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## K. VENTILATOR MANAGEMENT ON SHARED VENTILATOR

The ventilator should be adjusted as needed to maintain both patients in the following parameter ranges:

<b>Table 3. Recommended Range for Ventilator Settings during Ventilator Sharing<sup>a</sup></b>	
<b>Parameter</b>	<b>Recommended Range</b>
Ventilator mode	Pressure control
Tidal volume	6-8 mL/kg PBW in each patient
Peak inspiratory pressure	30 cmH <sub>2</sub> O or less <sup>b</sup>
Driving pressure	5-18 cmH <sub>2</sub> O <sup>b</sup>
Respiratory rate	12-36 breaths/min
Inspiratory time	0.6-1.0 seconds
PEEP	5-18 cmH <sub>2</sub> O
FiO <sub>2</sub>	21-100% (lowest tolerated) <sup>c</sup>
SpO <sub>2</sub>	92-100%
pH	7.20-7.45 <sup>d</sup> <i>If one patient is markedly acidemic and other alkalemic:</i> <ul style="list-style-type: none"> <li>• <i>Treat <b>acidemic</b> patient with <b>ventilator changes</b> as normally would do.</i></li> <li>• <i>Treat <b>alkalemic</b> patient by adding deadspace to ventilator circuit of affected patient to induce hypercapnia.</i></li> </ul>
Neuromuscular blockade	Mandatory for both patients while paired
<sup>a</sup> Patients who cannot be maintained within this range should be considered for their own ventilator where feasible. <sup>b</sup> Higher peak and driving pressures may be considered with expert consultation. Higher pressures may be required to maintain tidal ventilation as moisture buildup in the filters over time adds resistance to the circuit. <sup>c</sup> If one patient cannot tolerate FiO <sub>2</sub> below 100% but other can, consider transition to single-patient ventilator for dedicated support.	

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## L. WEANING STRATEGY

Recommended weaning strategy:

1. Ventilator settings in Table 3 should be weaned as tolerated.
2. Consider unpairing patients (single-patient ventilation) if:
  - a. If one patient seems to be improving but weaning is prohibited by other patient's condition
  - b. If one patient acutely worsens disproportionately to other
3. Once a patient tolerates driving pressure  $\leq 10$  cmH<sub>2</sub>O, PEEP  $\leq 10$  cmH<sub>2</sub>O, and FiO<sub>2</sub>  $\leq 40\%$ , consider transitioning that patient to single-patient ventilator for further weaning and screen for extubation.
4. Paralytics and sedation should not be stopped until patient is on single-patient ventilator.

## M. TRANSITION FROM SHARED TO SINGLE-PATIENT VENTILATOR

**Step 1:** Preoxygenate using the shared ventilator.

**Step 2:** Prepare a new ventilator and circuit for single patient ventilation as per local protocol.

**Step 3:** Confirm a circuit cap is available that fits on end of Y-connector. In most circumstances, the cap can be obtained from the new circuit being set up.

**Step 4:** Transition Patient A to single-patient ventilator via following steps in *immediate succession*.

1. Perform breath hold on ventilator (minimizes aerosols)
2. **Clamp endotracheal tube** of Patient A (minimizes aerosols and derecruitment).
3. Disconnect Patient A from shared ventilator circuit.
4. Connect Patient A to new circuit.
5. **Immediately unclamp endotracheal tube after patient on new circuit.**  
**Immediately place circuit cap on Y-piece of the now-disconnected shared circuit** that was occupied by Patient A. This cap will allow the former shared circuit to continue to support Patient B on that circuit.

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## N. VENTILATOR ALLOCATION SCHEMA FOR HOSPITAL

Ventilator Cluster	Use
Transport ventilators (single-patient)	<ul style="list-style-type: none"> <li>• Transport patients throughout hospital</li> <li>• Emergency department</li> </ul>
Rescue ventilators (single-patient)	<ul style="list-style-type: none"> <li>• Rescue a patient undergoing ventilator sharing who needs to be urgently placed back on single ventilator</li> </ul>
Shared ventilators	Only when deemed appropriate & necessary due to exhausted ventilator supply for well-paired patients
Single-patient ventilators	Need for individualized support: <ol style="list-style-type: none"> <li>1. Patient's ventilator needs must be individualized (Table 1)</li> <li>2. Patient ready for active weaning from ventilator</li> </ol>

At least one rescue ventilator should be placed near each cluster of patients that are supported by shared ventilators. Any hospital applying this protocol should determine the appropriate ratio of paired patients to backup ventilators for their facility.

It is *NOT* appropriate to support all patients with ventilator sharing. Patient selection must be carefully considered, and some ventilators must be reserved for patients who need individualized support or are ready to wean.

Ventilator sharing is most safely performed at centers with advanced expertise in invasive mechanical ventilation. A regional referral model may be appropriate to maximize the number of patients who may benefit while maintaining safety standards.

## O. ADMINISTRATIVE AND ETHICAL CONSIDERATIONS

Hospital administration should approve the protocol before use, acknowledging the unique ethical considerations. This protocol is only appropriate for consideration when (i) crisis standards have been instituted, (ii) there are not enough ventilators to meet demand for single-patient ventilation, and (iii) multiple patients are present for whom invasive ventilation has a reasonable probability of being life-saving.

Ethically, it must be recognized that a shared ventilator strategy is not the usual standard of care. However, in the setting of a mass crisis, such as the COVID-19 pandemic, the number of potentially rescuable patients may exceed the number of ventilators to support them. With the above safety measures, we believe this approach offers the best chance at saving the most lives. The use of a shared ventilator strategy should be discontinued as soon as a sufficient supply of ventilators becomes available.

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## APPENDIX 1

Ventilator-Sharing Shift Change Checklist	
Protocol	A copy of the full ventilator sharing protocol is at bedside
Power	Ventilator and NM3 A/C power are connected to emergency red outlets
Ventilator Settings	Acknowledge FiO <sub>2</sub>
	Acknowledge PEEP
	Acknowledge respiratory rate (RR)
	Acknowledge driving pressure
	Acknowledge inspiratory time
	Acknowledge combined tidal volume (Vt) on ventilator (patient A+B)
NM3	Acknowledge <i>patient-specific</i> tidal volume (Vt)
	Acknowledge <i>patient-specific</i> end-tidal CO <sub>2</sub>
Ventilator Alarms	Vt in pts A+B: Lower (A+B – 100 mL). Upper 250 mL > min
	RR: Lower 5 bpm < preset. Upper 5 bpm > preset
	Peak Pressure: Lower 5 cm H <sub>2</sub> O < preset. Upper 5 cm H <sub>2</sub> O > preset
	Minute ventilation: Lower (A+B) – 1 L/min. Upper (A+B) + 1 L/min
Emergency	2 clamps available
	2 ventilator circuit caps available
	2 extra ventilator circuits available
	2 T-pieces and 2 cuff connectors available
	Ambu bag available
	Back-up ventilator available in cluster
Circuit	Ensure patient wristband located on personal circuit for BOTH patients
	Circuit tubing lines free of tension
	Ensure T-piece and filters secure and well-positioned
	Inspect HEPA filter for soiling or saturation in BOTH patients
	Ensure back-up HEPA filter available for BOTH patients

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