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

From the Washington DC COVID-19 Co-Ventilation Task force
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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 FiO2 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 co-ventilation 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 SpaO2 is = or > 88% with usual manual bag ventilation, patient should be allocated to group 2. After 1 hour, ABG, Vt, ETCO2 and SpO2 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 SpO2 is <88% with manual bag ventilation, patient should be allocated to Group 3. Parameters (ABG, Vt, ETCO2 and SpO2) should again be assessed after 1 hour to determine if the patient is appropriate to remain in Group 3.

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 O2 requirements to the greatest extent possible.
3. **Reassessment and Group Reassignment**

If after 1 hour the SpO2 is less 88%, patient should be reallocated to the next higher group. We accept a lower SpO2 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**

**PC Settings and PEEP By Group**

<table>
<thead>
<tr>
<th>Group</th>
<th>PC</th>
<th>FIO2</th>
<th>PEEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20-25</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>25-30</td>
<td>90</td>
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<tr>
<td>4</td>
<td>30-35</td>
<td>100</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>35-40*</td>
<td>100</td>
<td>22</td>
</tr>
</tbody>
</table>

*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-ventilation or ventilator sharing system.

FOR PURPOSES OF CLARITY, 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 DERERecruitment 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 cmH₂O 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.
  - SpO₂ 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 CO₂ 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 FiO₂ 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 FiO2 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 SpO2 < 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

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


- 2 Plastic Tube Clamps (Image 1)
• 2 Standard Ventilation circuits. Each circuit should include (Image 2)
  o 6 feet Inspiratory corrugated tubing
  o 6 feet Expiratory corrugated tubing
  o 1 wye adaptor
  o 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
  o 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)
  o Option 2 (community sourced – if insufficient hospital supply )
    ▪ 2 CPVC CTS ¾ inch Tee (Image 10)
      • CTS= Copper Tube Size (ASTM D2846)
    ▪ 6 male to male adaptors
      • Hospital sourced 15 mm adapters (Image 11)
      • ¾ CPVC CTS pipe cut to 4 cm (Image 12)
        o CTS= Copper Tube Size
IMAGE 2 – Standard Ventilator Circuit

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

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 ¾ inch Tee

IMAGE 11 - Hospital sourced 15 mm adapters
Training and Resources
FAQs: (FEMA link). We hope to have this up soon


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

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