A. ADMINISTRATIVE AND ETHICAL CONSIDERATIONS

When the IMT determines that “Scarce Resource Allocation” for ventilators is in place – defined by the Surge group by % remaining ventilators - Senior IMT will approve the protocol before use, acknowledging the unique ethical considerations. The Scarce Resource Allocation Task Force must be notified whenever deployment of the protocol is being considered. It is NOT appropriate to support all patients with dual-patient ventilation. Patient selection must be carefully considered.

Ethically, it must be recognized that dual-patient ventilation is not the usual standard of care. However, in the setting of a mass crisis, such as the COVID19 pandemic, the number of potentially rescuable patients may exceed the number of ventilators to support them. With the below safety measures, we believe this approach offers the best chance at saving the most lives. Patient and family must be aware that protocol is being considered. The use of dual- patient ventilation should be discontinued as soon as a sufficient supply of ventilators becomes available.

B. 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 or heavy sedation (Goal: RASS = -5). Any extubation or tube dislodgement causing air leak would be detected by PEEP alarm immediately, even during dual-patient ventilation.

2. **One patient infecting the other.** This risk is mitigated by the antimicrobial filter placed between airflow of the two patients and by the plan to view any positive respiratory or blood culture as though it occurred in both patients sharing the ventilator.

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 capnography where available, 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 or heavy sedation (Goal: RASS = -5).

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:

- **Neuromuscular blockade (paralysis) or heavy sedation** ensures neither patient triggers the ventilator and helps mitigate risk of pendelluft in the patient not breathing spontaneously.

- **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.

- **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.

- **Similar mechanical support and lung compliance** for patients considering to be paired together to minimize risk of ventilation-induced lung injury or hypo/hyperventilation.

- **Ventilator alarms** are tightly adjusted to detect changes that would warrant bedside
This protocol is shared with our health care colleagues to increase knowledge about potential solutions to increase the capacity and access to mechanical ventilation during the COVID-19 crisis. Advocate Aurora Health does not warrant the contents or effectiveness of the protocol, and the use and implementation of this protocol should be first reviewed and evaluated with each hospital’s medical staff.

C. 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 (22mm X 22mm adapter, this adapter may be blue or clear in color)
6. Two antimicrobial filters (may be single-walled or dual-walled based on hospital supply)
7. Four one-way valves on each inspiratory and expiratory limb of circuit to minimize back-pressure

**NOTE: HEMF** (HME + antimicrobial filter in one device) **is recommended if available.**

- If you are using a HMEF, 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:

![Picture of equipment needed](image)
D. SETTING UP VENTILATOR FOR DUAL-PATIENT VENTILATION

**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 1](image1)

**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 2](image2)

**Step 3:** Connect both expiratory limb circuits (white) to either site of the **same** T-piece.

![Step 3](image3)

First circuit  Second circuit
**Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortages**

*Step 4:* Connect both inspiratory limb circuits (blue) to either side of the other T-piece.

*Step 5:* Connect T-piece with inspiratory limb (blue tubing) to inspiratory port on ventilator.
Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortages

**Step 6:** Connect T-piece with expiratory limb (white tubing) to expiratory port on ventilator.

*IMPORTANT:* 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 dual-patient ventilation.

*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.

E. VENTILATOR CIRCUIT SAFETY TEST

**Step 1:** Turn on new ventilator to be used for dual-patient ventilation. Run the system checks as you normally would per hospital policy.

*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 secure. Consider repeating leak test with a single circuit attached as done in usual practice.

- All ventilators tested by New York-Presbyterian Hospital supported 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:
- No ventilator alarms or errors occur.
- Both test lungs inflate and deflate at the same time and are equal with each breath.
- As available equipment permits, independently measure tidal volume in each test lung simultaneously to confirm they are similar.

F. VENTILATOR CIRCUIT SAFETY TEST

**Step 1:** Turn on new ventilator to be used for dual-patient ventilation. Run the system checks as you normally would per hospital policy.

**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 secure. Consider repeating leak test with a single circuit attached as done in usual practice.

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- No ventilator alarms or errors occur.
- Both test lungs inflate and deflate at the same time and are equal with each breath.
- As available equipment permits, independently measure tidal volume in each test lung simultaneously to confirm they are similar.
G. 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 both patients and allows room for ventilator titration if needed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Acceptable Limit in Either Patient</th>
<th>Acceptable Difference Between Patients (patient A – patient B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated time needing invasive ventilation</td>
<td>72 hours or higher</td>
<td></td>
</tr>
<tr>
<td>Tidal volume</td>
<td>6-8 mL/kg PBW</td>
<td></td>
</tr>
<tr>
<td>Driving pressure (ΔP = plateau pressure – PEEP)</td>
<td>5-16 cmH2O</td>
<td>0-6 cmH2O</td>
</tr>
<tr>
<td>PIP</td>
<td>&lt; 40 cmH2O</td>
<td>0-5 cmH2O</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>12-30 breaths/min</td>
<td>0-8 breaths/min</td>
</tr>
<tr>
<td>PEEP</td>
<td>5-18 cmH2O</td>
<td>0-5 cmH2O</td>
</tr>
<tr>
<td>FiO2</td>
<td>21-60%</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.30 or higher</td>
<td></td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>92-100%</td>
<td></td>
</tr>
<tr>
<td>Ventilator titration</td>
<td>No recent major changes as judged clinically</td>
<td></td>
</tr>
<tr>
<td>Neuromuscular blockade or heavy sedation (Goal = RASS -5)</td>
<td>No contraindication to initiation if not already receiving</td>
<td></td>
</tr>
<tr>
<td>Respiratory infectious status</td>
<td>Both patients have same infectious organism</td>
<td>None</td>
</tr>
<tr>
<td>Asthma or COPD</td>
<td>No severe baseline disease nor current exacerbation</td>
<td></td>
</tr>
<tr>
<td>Hemodynamic stability</td>
<td>No rapid vasopressor increase</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: PBW = predicted body weight, calculated as follows: PBW
males = 50 + 2.3 [height (inches) – 60]
PBW females = 45.5 + 2.3 [height (inches) – 60]
H. STEPWISE APPROACH TO MATCHING VENTILATOR SETTINGS

**Step 1:** In both patients: Respiratory effort must be eliminated as follows:
- Titrate sedation to unresponsive state (RASS = -5)
- Initiate continuous neuromuscular blockade (paralysis) with Rocuronium 1 mg/kg bolus followed by continuous infusion of 10 mcg/kg/min (usual range 4-16 mcg/kg/min). For patients with severe renal or hepatic impairment, initiate continuous neuromuscular blockade (paralysis) with Cisatracurium 0.2 mg/kg bolus followed by continuous infusion of 3 mcg/kg/min (usual range 0.5-10 mcg/kg/min).
- Reconfirm initial patient compatibility in Table 1

**Step 2:** In patient A (prior to pairing):
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$_2$: Unchanged from baseline unless adjustment needed for safety

**Step 3:** In patient B (prior to pairing):
1. Make note of the following baseline values:
   a. baseline driving pressure ($\Delta P = \text{plateau pressure} - \text{PEEP}$)
   b. baseline tidal volume (6-8 mL/kg PBW)
   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$_2$: Unchanged from baseline unless change needed for safety

**Step 4:** In both patients (prior to paring):
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$_2$: titrate to be the same in both patients while maintaining SpO$_2 \geq$ 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).
Ventilator Sharing Protocol: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortages

**Step 5:** In **both** patients (**prior to paring**):
1. **Driving pressure:** titrate to be the same in both patients.
   - Consider initial driving pressure adjustment set to average of the two patients.
2. **Inspiratory time:** titrate to be the same in both patients.
   - 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**
   - Confirm **minute-volume** remains within ± 2 liters/min baseline in each patient.
   - After 20 minutes, check **arterial or venous blood gas** in both patients to confirm pH & pCO₂ in acceptable range.
   - Confirm both patients remain not making any spontaneous breathing effort.
   - Confirm both patients now are tolerating **identical ventilator settings**.
   - Note these values for use in setting initial ventilator alarms (Table 2)

I. RECOMMENDED INITIAL VENTILATOR ALARM SETTINGS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Alarm</th>
<th>Upper Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (Vₜ)¹</td>
<td>(Vₜ in patients A+B) – 100 mL</td>
<td>250 mL above minimum alarm</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>5 breaths/min below preset value</td>
<td>5 breaths/min above preset value</td>
</tr>
<tr>
<td>Peak pressure</td>
<td>5 cmH₂O below preset value</td>
<td>5 cmH₂O above preset value</td>
</tr>
<tr>
<td></td>
<td>(preset = driving pressure + PEEP)</td>
<td>(preset = driving pressure + PEEP)</td>
</tr>
<tr>
<td>PEEP</td>
<td>2 cmH₂O below preset value</td>
<td>5 cmH₂O above preset value</td>
</tr>
<tr>
<td>Minute-volume¹</td>
<td>(minvol in patients A+B) – 1 liter/min</td>
<td>(minvol in patients A+B) + 1 liter/min</td>
</tr>
</tbody>
</table>

¹Values for Vₜ and MV 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

**IMPORTANT:** During dual-patient ventilation, ventilator may misestimate compressible gas volume in circuit. As a result, Vₜ may be incorrect by ~80 mL, with similar misestimation of minute-volume. Vₜ alarm may need to be adjusted, but then blood gas must be done to confirm adequate ventilation.
J. INITIATING DUAL-PATIENT VENTILATION

**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 FiO2 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. Distances from patients to ventilator must be measured to remain exactly the same.

**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 ± 2 liters/min baseline in each patient.
   b. pH & pCO2 on matched ventilator settings is in acceptable range.
   c. Both patients remain paralyzed and not making any spontaneous breathing effort.
3. Dual-patient ventilation circuit is operational and insufflates both test lungs as per Section D, Step 2.

**Step 3:** 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 4:** Complete following procedures to transition the patients to the new circuit:
1. New dual-patient ventilator is on with circuit connected and insufflating the two test lungs (Section D, Step 2).
2. Remove one test lung from one circuit of the new dual-patient ventilator and cap the circuit
3. Remove the other test lung from the dual-patient ventilator circuit.
4. 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.
5. Repeat for Patient B, connecting to the other circuit on the dual-patient ventilator.

**Step 5:** SAFETY CHECK after initiating dual-patient ventilation
1. Dual-patient tidal volume (on pressure control) is within ±100 mL of tidal volumes for patients A+B added together from just prior to dual-patient ventilation
2. Caregivers to remain at bedside for 10 minutes post initiation and remain nearby thereafter
3. Obtain vital signs Q30 minutes for 2 hours post initiation.
   a. SpO2 > 95% in each patient. Wean FiO2 as tolerated.
4. After 20 minutes, check arterial or venous blood gas in both patients to confirm pH & pCO2 in acceptable range.
5. Both patients remain not making any spontaneous breathing effort.
6. Maintain old ventilators at bedside until 20-minute blood gas results returned and deemed acceptable.
K. MONITORING & SUPPORT DURING DUAL-PATIENT VENTILATION

Recommended clinical monitoring includes:

1. Ventilator alarms carefully set (Table 2)
2. Continuous neuromuscular blockade or heavy sedation for duration of time that patients are paired
3. Continuous pulse-oximetry and telemetry for both patients
4. Frequent blood pressure check for both patients, either continuous (preferred) or otherwise checked every 5-15 minutes
5. **End-tidal CO₂** for both patients (if available)
6. **pH and pCO₂** via arterial or venous blood gas in both patients **at 2 hours, 4 hours, and then q8 hours**
7. **pH and pCO₂** via arterial or venous blood gas **20 minutes after every change** in ventilator support except FiO₂. Blood gases are to be obtained from both patients even when clinical interest may only be on one patient.
8. **Independent tidal volume monitoring**: Freestanding respiratory monitors to independently monitor each patient’s individual tidal volume and minute-volume are strongly advised for safety. For example, we have used 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.

L. CARING FOR PATIENTS RECEIVING DUAL-PATIENT VENTILATION

1. **Managing shift changes**: Each time staff change for patients undergoing dual-patient ventilation, the team should huddle to review key safety elements, including the following:
   - Availability of this protocol at bedside at all times
   - Paralysis of both patients with no spontaneous respiratory effort
   - Circuit configuration, including how to replace if ever dislodged or disconnected.
   - Availability of acute airway and respiratory backup support devices, including bag valve mask and rescue ventilator nearby.
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.
M. VENTILATOR MANAGEMENT DURING DUAL-PATIENT VENTILATION

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator mode</td>
<td>Pressure control</td>
</tr>
<tr>
<td>Tidal volume</td>
<td>6-8 mL/kg PBW</td>
</tr>
<tr>
<td>Peak inspiratory pressure</td>
<td>30 cmH(_2)O or less</td>
</tr>
<tr>
<td>Driving pressure</td>
<td>5-18 cmH(_2)O</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>12-30 breaths/min</td>
</tr>
<tr>
<td>Inspiratory time</td>
<td>0.6-1.0 seconds</td>
</tr>
<tr>
<td>PEEP</td>
<td>5-16 cmH(_2)O</td>
</tr>
<tr>
<td>FiO(_2)</td>
<td>21-100% (lowest tolerated)(^b)</td>
</tr>
<tr>
<td>SpO(_2)</td>
<td>92-100%</td>
</tr>
<tr>
<td>pH</td>
<td>7.25-7.45</td>
</tr>
</tbody>
</table>

*Permissive hypercapnia tolerating pH as low as 7.20 may be considered where clinically appropriate.*

*If one patient is markedly acidemic and other alkalemic:*
  - Treat acidemic patient with ventilator changes as normally would do.
  - Treat alkalemic patient by adding deadspace to ventilator circuit of affected patient to induce hypercapnia.

**Neuromuscular blockade or heavy sedation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mandatory for both patients while paired</th>
</tr>
</thead>
</table>

\(^a\)Patients who cannot be maintained within this range should be considered for their own ventilator where feasible.

\(^b\)If one patient cannot tolerate FiO\(_2\) below 100% but other can, consider transition to single-patient ventilator for dedicated support.

N. 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 ≤ 10, PEEP ≤ 10, and FiO\(_2\) ≤ 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.
O. TRANSITION TO SINGLE-PATIENT VENTILATION

**Step 1:** Prepare a new ventilator and circuit for single patient ventilation as per local protocol.

**Step 2:** 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 3:** Transition Patient A from dual-patient to single-patient ventilator, clamping endotracheal tube during transfer to minimize aerosol and de-recruitment.

**Step 4:** Immediately place circuit cap on Y-piece of now-disconnected dual-patient circuit.
  - *This cap will allow the former dual-patient circuit to continue to support Patient B on that circuit.*

P. VENTILATOR ALLOCATION SCHEMA FOR HOSPITAL

<table>
<thead>
<tr>
<th>Ventilator Cluster</th>
<th>Use</th>
</tr>
</thead>
</table>
| Transport ventilators (single-patient) | • Transport patients throughout hospital  
|                                     | • Emergency department                                               |
| Rescue ventilators (single-patient)  | • Rescue a patient undergoing dual-patient ventilation who needs to be urgently placed back on single ventilator |
| Dual-patient ventilators             | Only when deemed appropriate & necessary due to exhausted ventilator supply |
| Single-patient ventilators           | Need for individualized support:  
|                                     | 1. Patient’s ventilator needs must be individualized (Table 1)  
|                                     | 2. Patient ready for active weaning from ventilator                 |

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

References