VENTILATOR SHARING PROTOCOL (DUAL AND MULTIPLE PATIENTS)
ADAPTED FROM THE NEW YORK PRESBYTERIAN HOSPITAL PROTOCOL

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COVID-19 MIGHT OUT-STRIP THE NUMBER OF MECHANICAL VENTILATORS AVAILABLE TO US. THIS HAS LED TO INTEREST IN USING A SINGLE VENTILATOR TO SUPPORT MULTIPLE PATIENTS. THIS PROTOCOL WILL BE SUBJECT TO CHANGE WITH AS INPUTS FROM SPECIALISTS CONTINUE TO POUR IN.

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 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.
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 (swinging of air in different regions of the lung) in the patient not breathing spontaneously.

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, cancelling 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. Because tidal volume and minute-volume reflect the additive values from both patients combined, it is essential that ventilator alarms be adjusted expertly to detect small deviations in either of these parameters.

**EQUIPMENTS AND SUPPLIES NEEDED:**

The same principle applies to more than 2 patients for a maximum of 4 patients if the ventilator has the capabilities.

1. One ventilator
2. Two sets of patient tubing
3. Two t-pieces (often used for “t-piece” spontaneous breathing trials)
4. Two connector cuffs
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

5. 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.

6. 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.

7. 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.

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

9. 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.

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

11. 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. 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.
Table 1: Recommended initial patient compatibility criteria. If patients do not meet all of these criteria, pairing them on a single ventilator is not recommended.

<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 ((\Delta P = \text{plateau pressure} – \text{PEEP}))</td>
<td>5-16 cmH O</td>
<td>0-6 cmH O</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>12-30 breaths/min</td>
<td>0-8 breaths/min</td>
</tr>
<tr>
<td><strong>FiO</strong></td>
<td>21-60%</td>
<td></td>
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<tr>
<td>---</td>
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<td></td>
</tr>
</tbody>
</table>

| **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 |

**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]

**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:
   1. baseline driving pressure (\(\Delta P = \text{plateau pressure} - \text{PEEP}\))
   2. baseline tidal volume
   3. baseline respiratory rate

2. **Pressure control ventilation (PCV) mode** with: baseline driving pressure.

   - **Driving pressure**: set to match measured baseline driving pressure.
   - **Inspiratory time**: adjust between 0.6 to 1.0 seconds to achieve tidal volume approximating baseline

The same should be done to patient B as was done to patient A above.

**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\(_2\)**: titrate to be the same in both patients while maintaining \(\text{SpO}_2 \geq 95\%\).

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).

**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 ± 2 liters/min baseline in each patient*.
   b. After 20 minutes, check *arterial or venous blood gas* in both patients to confirm pH & pCO₂ in acceptable range.
   c. Confirm both patients remain *paralyzed* and not making any spontaneous breathing effort.
### 5. Table 2. Recommended Initial Ventilator Alarm Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Alarm</th>
<th>Upper Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_T )</td>
<td>((V_T \text{ in patients A+B}) - 100 \text{ mL})</td>
<td>250 \text{ 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 cmH(_2)O below preset value (preset = driving pressure + PEEP)</td>
<td>5 cmH(_2)O above preset value (preset = driving pressure + PEEP)</td>
</tr>
<tr>
<td>PEEP</td>
<td>2 cmH(_2)O below preset value</td>
<td>5 cmH(_2)O above preset value</td>
</tr>
<tr>
<td>Minute-volume(^a)</td>
<td>((\text{minvol in patients A+B}) - 1 \text{ liter/min})</td>
<td>((\text{minvol in patients A+B}) + 1 \text{ liter/min})</td>
</tr>
</tbody>
</table>

**IMPORTANT:** During dual-patient ventilation, ventilator may misestimate compressible gas volume in circuit. As a result, \( V_T \) may be incorrect by \( \sim 80 \text{ mL} \), 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.
**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:

6. **Increase FiO\textsubscript{2} to 100%** for preoxygenation prior to transfer.

7. 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 ± 2 liters/min baseline in each patient.*
   
   b. **pH & pCO\textsubscript{2}** 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 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).

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. **SpO2 > 95%** in each patient. Wean FiO₂ as tolerated.

3. After 20 minutes, check **arterial or venous blood gas** in both patients to confirm pH & pCO₂ 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.

**MONITORING AND SUPPORT DURING DUAL VENTILATION**

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
   - Continuous telemetry for both patients

4. Frequent blood pressure check for both patients, either continuous (preferred) or otherwise checked every 5-15 minutes

   **THE REST CAN BE SKIPPED IF EQUIPMENT IS NOT AVAILABLE**

5. **End-tidal CO**₂ for both patients (if available)

6. **pH and pCO**₂ via arterial or venous blood gas in both patients at 2 hours, 4 hours, and then q8 hours

7. **pH and pCO**₂ via arterial or venous blood gas **20 minutes after every change** in ventilator support except FiO₂.

8. **Independent tidal volume monitoring**

**CARING FOR PATIENTS RECEIVING DUAL PATIENT VENTILATION**

8. *Managing shift changes*: Each time staff change for patients undergoing dual-patient ventilation, the team should huddle to review key safety elements, including the
a. Availability of this protocol at bedside at all times

b. Paralysis of both patients with no spontaneous respiratory effort

c. Circuit configuration, including how to replace if ever dislodged or disconnected.

d. Availability of acute airway and respiratory backup support devices, including bag valve mask and rescue ventilator nearby.

9. *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.

10. *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.

### Table 3. Recommended Range of Ventilator Settings during Dual-Patient Ventilation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
### Ventilator settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ventilator mode</strong></td>
<td>Pressure control</td>
</tr>
<tr>
<td><strong>Tidal volume</strong></td>
<td>6-8 mL/kg PBW</td>
</tr>
<tr>
<td><strong>Peak inspiratory pressure</strong></td>
<td>30 cmH₂O or less</td>
</tr>
<tr>
<td><strong>Driving pressure</strong></td>
<td>5-18 cmH₂O</td>
</tr>
<tr>
<td><strong>Respiratory rate</strong></td>
<td>12-30 breaths/min</td>
</tr>
<tr>
<td><strong>Inspiratory time</strong></td>
<td>0.6-1.0 seconds</td>
</tr>
<tr>
<td><strong>PEEP</strong></td>
<td>5-16 cmH₂O</td>
</tr>
<tr>
<td><strong>FiO₂</strong></td>
<td>21-100% (lowest tolerated)</td>
</tr>
<tr>
<td><strong>SpO₂</strong></td>
<td>92-100%</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7.25-7.45&lt;sup&gt;c&lt;/sup&gt; &lt;br&gt; If one patient is markedly acidemic and other alkalemic: Treat <strong>acidemic</strong> patient with <strong>ventilator changes</strong> as normally would do. Treat <strong>alkalemic</strong> patient by adding deadspace to ventilator circuit of affected patient to induce hypercapnia.</td>
</tr>
<tr>
<td><strong>Neuromuscular blockade</strong></td>
<td>Mandatory for both patients while paired</td>
</tr>
</tbody>
</table>

**WEANING STRATEGY**

Recommended weaning strategy:

11. Ventilator settings in Table 3 should be weaned as
tolerated.

12. 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

13. Once a patient tolerates driving pressure ≤ 10, PEEP ≤ 10, and FiO₂ ≤ 40%, consider transitioning that patient to single-patient ventilator for further weaning and screen for extubation.

14. Paralytics and sedation should not be stopped until patient is on single-patient ventilator.

TRANSITION TO A SINGLE PATIENT VENTILATOR

**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 derecruitment.

**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.
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 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 above safety measures, we believe this approach offers the best chance at saving the most lives. The use of dual-patient ventilation should be discontinued as soon as a sufficient supply of ventilators becomes available.

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REFERENCES
