

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

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Columbia University Vagelos College of Physicians and 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. The most recent version of this protocol can be found online at: <http://protocols.nyp.org/>

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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 could 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.
10. *Only medical-grade equipment and supplies manufactured for clinical care applications* are considered to ensure product durability and patient safety.
11. *This protocol incorporates our clinical experience with the shared ventilator strategy in COVID19 patients with acute respiratory distress syndrome.* Substantial deviations from this protocol are not advised without careful bench and clinical evaluation and reconsideration of safety features to avoid unintended consequences.

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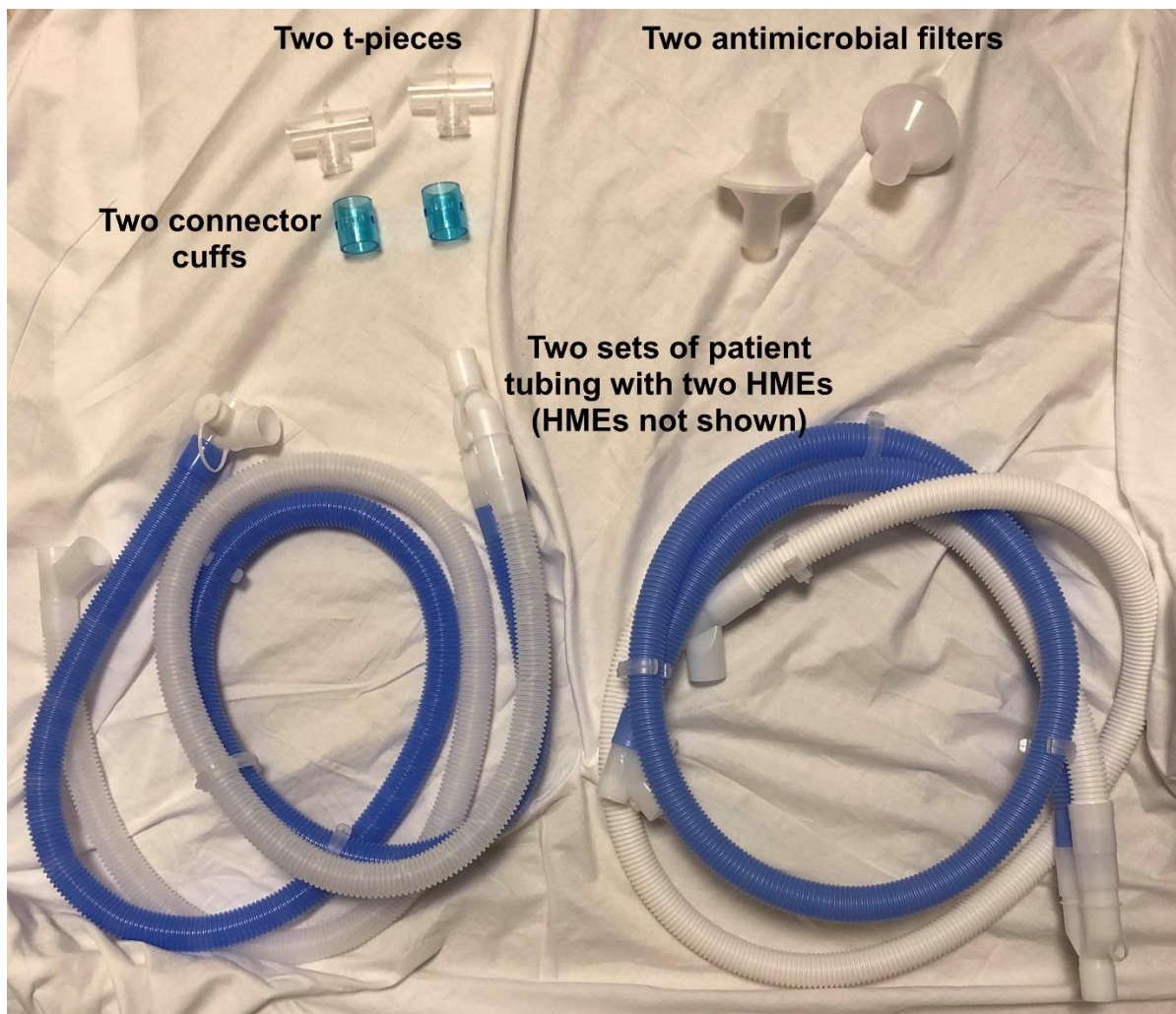
B. EQUIPMENT & SUPPLIES

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 strongly 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.**

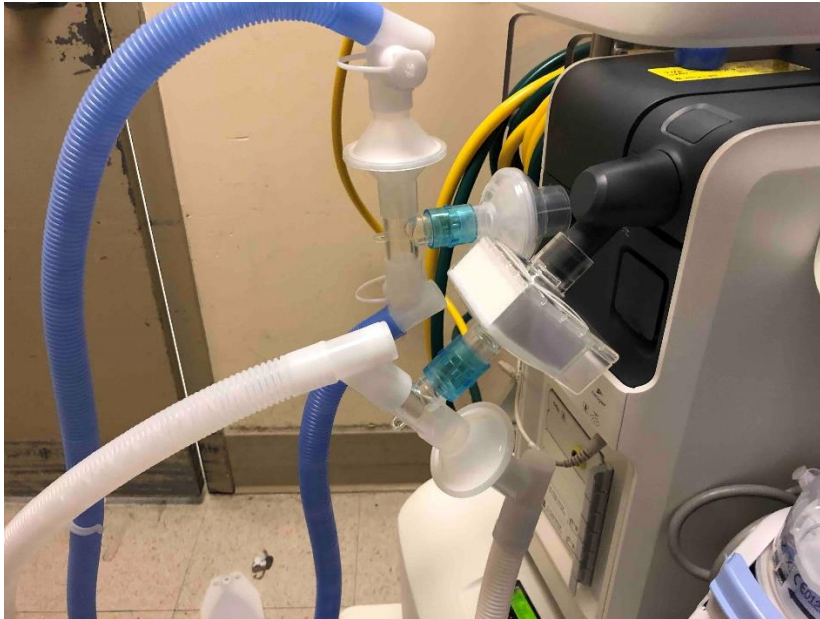


Step 5: Connect T-piece with inspiratory limb (blue tubing) to inspiratory port on ventilator.



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



Step 7: Place HME or HMEF inline at 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 at the endotracheal tube as you normally would. With an HMEF, separate antimicrobial filters are unnecessary but may be used for redundant infection control measures.

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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. This error may occur because the compressible volume calculation of the circuit reveals a value exceeding the expected range. If such error occurs during leak test, double-check all connections to ensure they are tight. 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. **Ventilator-displayed inspiratory and expiratory tidal volumes (VTi and VTe) are similar to each other.** A large difference between these parameters strongly suggests presence of an air leak.
3. Both test lungs inflate and deflate at the same time with each tidal breath.
4. **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.

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.		
Parameter	Acceptable Limit in Either Patient	Acceptable Difference Between Patients (patient A – patient B)
Anticipated time needing invasive ventilation	72 hours or higher	
Tidal volume	4-8 mL/kg PBW	
Driving pressure ($\Delta P = \text{plateau pressure} - \text{PEEP}$)	5-16 cmH ₂ O	0-6 cmH ₂ O ^a
Respiratory rate	12-30 breaths/min	0-8 breaths/min
PEEP	5-18 cmH ₂ O	0-5 cmH ₂ O
FiO ₂	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 respiratory pathogen	None
Asthma or COPD	No severe baseline disease nor current exacerbation	
Hemodynamic stability	No rapid vasopressor increase	
<p>^a Between-patient difference in driving pressure is the most important parameter to minimize in assessing potential compatibility of two patients.</p> <p><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]</p>		

Screening for eligible patients may be done most efficiently using an electronic health record (EHR), if available. Within the EHR, consider generating a patient census report that includes patient name, medical record number, bed location, the above respiratory parameters, and two calculated fields: driving pressure (equal to plateau pressure – PEEP) and “PIP-PEEP” (equal to peak inspiratory pressure minus PEEP). If plateau pressure is not documented, the field “PIP-PEEP” can be used as a substitute for initial screening. Sort the report by driving pressure (or “PIP-PEEP”) to readily identify patients within the above-specified ranges for this parameter. Then, view other settings and criteria to confirm eligibility. If all criteria are met, go to bedside and reconfirm eligibility, including performance of plateau pressure maneuver to calculate driving pressure if not recently performed and documented. Once a potential match is identified, confirm appropriateness with clinical team for each patient and then proceed with matching ventilator settings (Section F).

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F. STEPWISE APPROACH TO MATCHING VENTILATOR SETTINGS

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

1. Titrate sedation to RASS -5 (unresponsive)
2. Initiate **continuous neuromuscular blockade** to achieve respiratory muscle paralysis. Drug and dosing depend on clinical context and drug availability. **Cisatracurium** is preferred if available.
3. **Confirm paralysis** is achieved with **deep physical stimulation** and **endotracheal tube suction**.
 - a. Train of four (TOF) may not correlate reliably with passive ventilation. Eliminating TOF from monitoring is reasonable to minimize unnecessary staff entry/exposure into room.
4. 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 near baseline.
 - c. **Respiratory rate, PEEP, and FiO₂**: Unchanged from baseline unless change 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 initial measured driving pressure.
 - b. **Inspiratory time**: adjust between 0.6 to 1.0 seconds to achieve tidal volume near baseline.
 - c. **Respiratory rate, PEEP, and FiO₂**: 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. **FiO₂**: titrate to be the same in both patients while maintaining SpO₂ ≥ 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. **Remove any deadspace tubing** unless deemed clinically necessary.
2. **Driving pressure:** titrate to be the same in both patients.
 - a. Consider initial driving pressure adjustment set to average of the two patients.
3. **Inspiratory time:** titrate to be the same in both patients, between 0.6 to 1.0 seconds.
 - a. If tidal volume not within desired range, increase inspiratory time up to 1.0 seconds before adjusting driving pressure.
4. **Respiratory rate:** titrate to be the same in both patients.
5. **SAFETY CHECK**
 - a. Confirm **minute-volume** remains **within ± 2 liters/min baseline in each patient**.
 - b. **Measure auto-PEEP.** Adjust inspiratory time and respiratory rate if needed to maintain intrinsic PEEP (iPEEP) < 5 cmH₂O above set PEEP.
 - c. After 20 minutes, check **arterial blood gas** in both patients to confirm pH & pCO₂ are within acceptable range.
 - d. Confirm both patients remain **paralyzed** and not making any spontaneous breathing effort.
 - e. Confirm both patients now are tolerating **identical ventilator settings**.
 - f. Note these values for use in setting initial ventilator alarms (Table 2)

G. RECOMMENDED INITIAL VENTILATOR ALARM SETTINGS

Table 2. Recommended Initial Ventilator Alarm Settings		
Parameter	Lower Alarm	Upper Alarm
Tidal volume (V_T) ^a	(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 ₂ O below preset value (preset = driving pressure + PEEP)	5 cmH ₂ O above preset value (preset = driving pressure + PEEP)
PEEP	2 cmH ₂ O below preset value	5 cmH ₂ O above preset value
Minute-volume ^a	(minvol in patients A+B) – 1 liter/min	(minvol in patients A+B) + 1 liter/min
^a 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 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**.

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 are within 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 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. 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. Perform breath hold on ventilator (minimizes aerosols)
 - b. **Clamp endotracheal tube** of Patient A (minimizes aerosols and derecruitment).
 - c. Disconnect Patient A from old (single-patient) ventilator circuit.
 - d. Connect Patient A to new circuit.
 - e. **Immediately unclamp endotracheal tube after patient on new circuit.**
4. Repeat for Patient B, connecting to the other circuit on the shared ventilator.

Step 5: SAFETY CHECK after initiating ventilator sharing:

1. **Patient-specific tidal volume** is within ± 50 mL of tidal volumes just prior to shared 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.

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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, continuous (preferred) or checked every 5-15 minutes
6. **End-tidal CO₂** for both patients.
 - a. If limited availability of capnographs, shared ventilator patients should be prioritized.
7. **pH and pCO₂** via arterial or venous blood gas in both patients **at 2 hours, 4 hours, and then q8 hours**
 - a. **More frequent blood gases (every 2-4 hours) are required if patient-specific capnography and tidal volume monitoring is not available.**
8. **pH and pCO₂** via arterial or venous blood gas **20 minutes after every change** in ventilator support except FiO₂.
9. **Independent tidal volume monitoring:** Freestanding respiratory monitors to independently monitor each patient's individual tidal volume and minute-volume are strongly preferred for safety if available. 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. More frequent arterial blood gases are required if independent tidal volume or capnography monitoring is not available.
10. If an independent tidal volume monitor is unavailable, the following procedure can estimate patient-specific tidal volume at the moment of bedside evaluation (adapted from Covid-19 Co-Ventilation Task Force). It does *not* replace the role for monitoring patient-specific tidal volume and capnography continuously whenever possible.
 - a. Note tidal volume reported on ventilator screen
 - b. Clamp endotracheal tube of Patient A for 3-5 breaths. Ventilator now reports approximate tidal volume of Patient B. Tidal volume of Patient A = tidal volume unclamped minus Patient B.
 - c. Unclamp endotracheal tube of Patient A.

*****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, patient-specific tidal volume, or frequent 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.
4. **Blood gases:** Whenever a blood gas is performed on one patient, it should also be performed on the other patient to ensure all needed data are available to guide ventilator management.
5. **Routine ventilator checks:** All routine ventilator checks, such as by respiratory therapist, should include inspection of full length of the circuit from ventilator to each patient's endotracheal tube. In addition to routine checks, special attention should be given to the following:
 - a. Cuff connector properly seated deep on ventilator inspiratory and expiratory ports
 - b. T-piece properly seated deep within cuff connector
 - c. Circuits tubing and antimicrobial filters properly seated firmly on T-piece arms
 - d. Circuit tubing Y-connector tightly secured to each patient's endotracheal tube
 - e. Endotracheal tube positioned properly at lip/teeth with cuff properly inflated for each patient
 - f. Ventilator parameters and alarms within recommended ranges
 - g. Patient-specific tidal volume and end-tidal CO₂, if available on independent monitor

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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:

Table 3. Recommended Range for Ventilator Settings during Ventilator Sharing ^a	
Parameter	Recommended Range
Ventilator mode	Pressure control
Tidal volume	4-8 mL/kg PBW for each patient (seen on NM3 monitor)
Peak inspiratory pressure	35 cmH ₂ O or less ^b
Driving pressure	5-18 cmH ₂ O ^b
Respiratory rate	12-36 breaths/min
Inspiratory time	0.6-1.0 seconds
PEEP	5-18 cmH ₂ O
FiO ₂	21-100% (lowest tolerated) ^c
SpO ₂	92-100%
pH	7.20-7.45 ^d <i>If one patient is markedly acidemic and other alkalemic:</i> <ul style="list-style-type: none"> • <i>Treat respiratory acidosis with ventilator changes as normally would do.</i> • <i>Treat respiratory alkalosis by adding deadspace to ventilator circuit of affected patient to induce rebreathing and increase PaCO₂.</i>
Deep sedation and neuromuscular blockade	Mandatory for both patients while paired to ensure that neither patient triggers the ventilator or makes respiratory effort
<p>^a Patients who cannot be maintained within this range should be considered for their own ventilator where feasible.</p> <p>^b 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 or HME over time adds resistance to the circuit, or if compliant circuit tubing is used. Even in the pressure-control mode, peak inspiratory pressure may not equal plateau pressure unless airflow is zero at end-inspiration.</p> <p>^c If one patient cannot tolerate FiO₂ below 100% but other can, consider transition to single-patient ventilator for dedicated support.</p>	

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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 ≤ 10 cmH₂O, PEEP ≤ 10 cmH₂O, and FiO₂ $\leq 50\%$, consider transitioning that patient to single-patient ventilator for further weaning and screen for extubation.
 - a. The threshold for weaning and extubation may depend in part on availability of high-flow nasal cannula to provide greater noninvasive respiratory support.
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.**
6. **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"> • Transport patients throughout hospital • Emergency department • Continuous support as single-patient ventilators in less severe cases as functionality and supply permit
Conventional single-patient ventilators	Need for individualized support: <ul style="list-style-type: none"> • Patient's ventilator needs must be individualized (Table 1) • Patient ready for active weaning from ventilator
Repurposed anesthesia machine ventilators (single-patient)	<ul style="list-style-type: none"> • In operating room or designated areas where space and technical expertise for anesthesia machine exist
Repurposed non-invasive ventilators that can be adapted to invasive ventilation (single-patient)	<ul style="list-style-type: none"> • Patients with less severe disease for whom level of support from this device is adequate • Ventilator weaning for patients near ready for extubation
Shared ventilators (dual-patient)	<ul style="list-style-type: none"> • For carefully paired patients only when deemed appropriate and necessary due to exhausted ventilator supply
Rescue ventilators (single-patient)	<ul style="list-style-type: none"> • Rescue a patient undergoing ventilator sharing who needs to be urgently placed back on single ventilator

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. Some ventilators must be reserved for patients who need individualized support or are ready to wean.

O. REGIONAL COORDINATION OF VENTILATORS

Ventilator sharing is most safely performed at centers with **requisite expertise in respiratory physiology and complex ventilator management**. Use outside of such a setting may increase risk of harm to both patients. A regional referral model that includes regional coordination of ventilators and patient flow may be appropriate to maximize the number of patients who benefit while maintaining safety standards.

This ventilator-sharing strategy does not obviate the need for more ventilators. It may buy time to move ventilators to where they are most needed. In a worst-case scenario where no such ventilators are available to relocate, careful allocation of ventilator use according to the ventilator allocation schema (Section N) still may increase the number of patients who can be supported and lives saved.

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P. 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 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 shared ventilator strategy can be adopted ethically only in tandem with hospital policies on withdrawal or withholding of life sustaining treatment. 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 ₂
	Acknowledge PEEP
	Acknowledge respiratory rate (RR)
	Acknowledge driving pressure
	Acknowledge inspiratory time
	Acknowledge combined tidal volume (Vt) on ventilator (patient A+B)
NM3 Resp. Monitor	Acknowledge <i>patient-specific</i> tidal volume (Vt)
	Acknowledge <i>patient-specific</i> end-tidal CO ₂
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 ₂ O < preset. Upper 5 cm H ₂ 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
	Manual ventilator (e.g. ambu bag) available
	Rescue 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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APPENDIX 2

Emergency & Trouble Shooting Card for Ventilator-Sharing	
Issue	Actions
Tidal volume low	<ul style="list-style-type: none"> • Check patient-specific end-tidal CO₂ and tidal volume on NM3 monitor to identify patient likeliest to be source of issue. Salient change in patient-specific end-tidal CO₂ or decrease in patient-specific tidal volume indicates patient likeliest affected. • Check for kink or obstruction in circuit tubing or endotracheal tube and resolve if present. • Preoxygenate then suction patient likely affected based on end-tidal CO₂ and tidal volume. • Check HMEF (HEPA filter) at endotracheal tube of both patients for excessive water accumulation. Change HMEF if needed, following procedures for ventilator circuit disconnect. • Check antimicrobial filters in split circuit near ventilator inlet/outlet for visible soiling or water accumulation. If soiled or with water accumulation, notify ventilator-sharing team of need for it to be changed. • If above measures do not resolve issue, notify respiratory therapist, physician, & ventilator-sharing team immediately for assistance.
Hypoxemia in one or both patients	<ul style="list-style-type: none"> • Increase ventilator FiO₂ and evaluate for causes as you normally would.
Circuit air leak (ventilator alarm or inspired tidal volume more than 100 mL greater than expired tidal volume)	<ul style="list-style-type: none"> • Notify respiratory therapist, physician, & ventilator-sharing team immediately for assistance. • Confirm endotracheal tube cuff sufficiently inflated in both patients. • Confirm endotracheal tube position from lip/teeth unchanged in both patients. • Visually inspect full length of circuit from ventilator to each endotracheal tube for possible leak source and correct leak if identified. Possible leak sources to be resolved include: <ul style="list-style-type: none"> • Endotracheal tube cuff not sufficiently inflated in either patient • Endotracheal tube dislodged in either patient • Endotracheal tube pilot line or balloon damaged in either patient • Circuit tubing Y-connector not tightly connected to endotracheal tube in either patient • Circuit tubing or antimicrobial filter not tightly connected to T-piece arms • Cuff connector not firmly pressed all the way into T-piece at correct angle • If leak results in one or both patients not receiving adequate support and is not promptly resolved with above measures, bring rescue ventilator to bedside and prepare for transitioning patients back to single-patient ventilation. This is most safely done with ventilator-sharing team's assistance. Prepare and use manual ventilator (e.g. ambu bag) if necessary.
Circuit disconnect	<ul style="list-style-type: none"> • Increase ventilator FiO₂ to 100% immediately. • Reconnect circuit immediately if confident in configuration (photo on page 6). • Notify respiratory therapist, physician, & ventilator-sharing team immediately for assistance. • Prepare manual ventilator (ambu bag) and/or rescue ventilator as indicated.
Endotracheal tube pilot line or balloon damaged	<ul style="list-style-type: none"> • If pilot line/balloon cannot promptly be repaired, prepare for tube exchange. • When disconnecting the ventilator circuit during tube exchange, cap the circuit immediately to ensure other patient continues to receive full support. Remove cap to reconnect patient back to shared circuit when functioning endotracheal tube is replaced.
Self-extubation	<ul style="list-style-type: none"> • Cap circuit of the extubated patient immediately to ensure other patient continues to receive full support. • Prepare for reintubation as appropriate.
Cardiac arrest	<ul style="list-style-type: none"> • Use rescue ventilator or manual ventilator (ambu bag) during CPR, following instructions to separate arresting patient from shared circuit. • Cap circuit of the disconnected patient immediately to ensure other patient continues to receive full support. • Monitor the non-arresting patient for continued stability.

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