

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

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Columbia University College of Physicians & Surgeons
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Current Working Protocol – Subject to Revision

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

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A. 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 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, canceling the inspiratory cycle & risking hypoventilation.
3. *Pressure-control mode* also ensures that if one patient occultly makes spontaneous inspiratory efforts despite paralysis, the patient effort does not “steal” tidal volume from the other patient as would occur in volume-control.
4. *Similar mechanical support needs* for patients considering to be paired together to minimize risk of deleterious ventilation-induced lung injury or hypo/hyperventilation.
5. *Ventilator alarms* are tightly adjusted to detect changes that would warrant bedside evaluation. 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.

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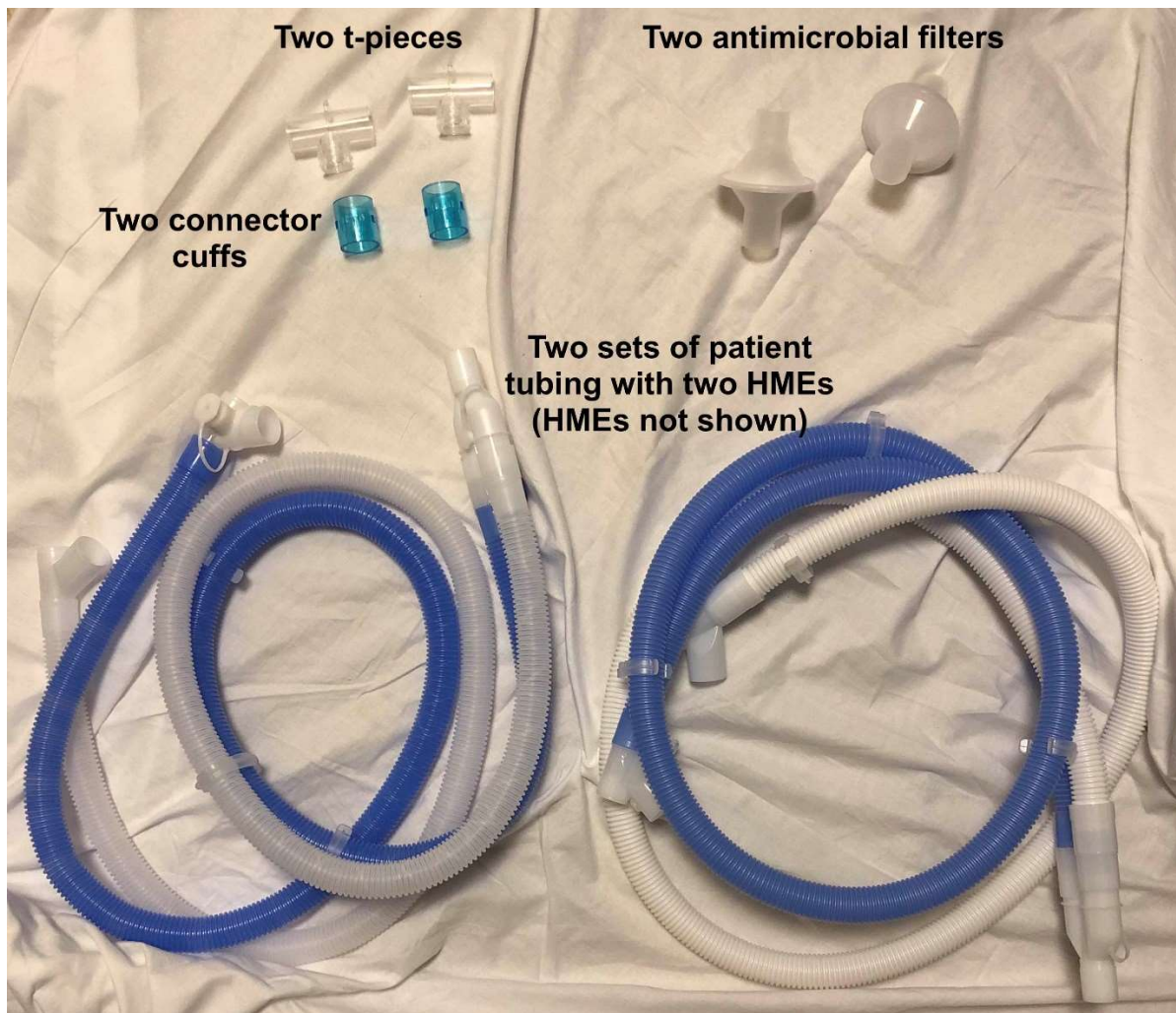
B. EQUIPMENT & SUPPLIES

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

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

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

Picture of equipment needed:



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C. SETTING UP 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 2: Connect antimicrobial filter to one side of T-piece.*

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



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



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



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



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



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

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

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D. 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 local institutional practice

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

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

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

Step 4: SAFETY CHECK: Observe the following.

1. No ventilator alarms or errors occur.
2. Both test lungs inflate and deflate at the same time with each tidal breath.
3. As available equipment permits, independently measure tidal volume in each test lung simultaneously to confirm they are similar.

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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	6-8 mL/kg PBW	
Driving pressure ($\Delta P = \text{plateau pressure} - \text{PEEP}$)	5-16 cmH ₂ O	0-6 cmH ₂ O
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 infectious organism	None
Asthma or COPD	No severe baseline disease nor current exacerbation	
Hemodynamic stability	No rapid vasopressor increase	
<i>Abbreviations:</i> PBW = predicted body weight, calculated as follows: PBW males = $50 + 2.3 [\text{height (inches)} - 60]$ PBW females = $45.5 + 2.3 [\text{height (inches)} - 60]$		

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F. STEPWISE APPROACH TO MATCHING VENTILATOR SETTINGS

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

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

Step 2: In **patient A:**

1. Make note of the following baseline values:
 - a. baseline driving pressure (ΔP = plateau pressure – 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 FiO₂:** Unchanged from baseline unless adjustment needed for safety

Step 3: In **patient B:**

1. Make note of the following baseline values:
 - a. baseline driving pressure (ΔP = plateau pressure – 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 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. **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.
 - d. Confirm both patients now are tolerating **identical ventilator settings.**
 - e. Note these values for use in setting initial ventilator alarms (Table 2)

G. RECOMMENDED INITIAL VENTILATOR ALARM SETTINGS

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 dual-patient ventilation, 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.

H. 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***.

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 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.

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I. MONITORING & SUPPORT DURING DUAL-PATIENT 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
4. Continuous telemetry for both patients
5. Frequent blood pressure check for both patients, either continuous (preferred) or otherwise checked every 5-15 minutes
6. **End-tidal CO₂** for both patients (if available)
7. **pH and pCO₂** via arterial or venous blood gas in both patients **at 2 hours, 4 hours, and then q8 hours**
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 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.

J. 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:
 - 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.
2. *Culture results and infection considerations:* Despite use of antibacterial/antiviral filters, there is no guarantee they are universally protective. Therefore, **all respiratory and blood culture results from one patient should be viewed as potentially applying to both patients.**
3. *Routine care procedures:* Any procedure that could contribute to respiratory compromise in one patient should not be done in both patients simultaneously. Such procedures include but are not limited to the following: suctioning, patient repositioning, endotracheal tube repositioning, or upper body central venous catheter insertion.

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K. VENTILATOR MANAGEMENT DURING DUAL-PATIENT VENTILATION

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

Table 3. Recommended Range of Ventilator Settings during Dual-Patient Ventilation ^a	
Parameter	Recommended Range
Ventilator mode	Pressure control
Tidal volume	6-8 mL/kg PBW
Peak inspiratory pressure	30 cmH ₂ O or less
Driving pressure	5-18 cmH ₂ O
Respiratory rate	12-30 breaths/min
Inspiratory time	0.6-1.0 seconds
PEEP	5-16 cmH ₂ O
FiO ₂	21-100% (lowest tolerated) ^b
SpO ₂	92-100%
pH	7.25-7.45 ^c <i>If one patient is markedly acidemic and other alkalemic:</i> <ul style="list-style-type: none"> • 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	Mandatory for both patients while paired
^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. ^c Permissive hypercapnia tolerating pH as low as 7.20 may be considered where clinically appropriate.	

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 , PEEP ≤ 10 , and FiO₂ $\leq 40\%$, consider transitioning that patient to single-patient ventilator for further weaning and screen for extubation.
4. Paralytics and sedation should not be stopped until patient is on single-patient ventilator.

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M. 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 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.

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
Rescue ventilators (single-patient)	<ul style="list-style-type: none"> 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: <ol style="list-style-type: none"> Patient's ventilator needs must be individualized (Table 1) 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.

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

O. ADMINISTRATIVE AND ETHICAL CONSIDERATIONS

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

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

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