American Association for Respiratory Care

SARS CoV-2

The current pandemic with SARS CoV-2 represents the realization of imagined scenarios with serious consequences. The current viral interstitial pneumonia has resulted in severe hypoxemic respiratory failure, overcrowded ICUs, equipment and personnel shortages, and significant mortality. Projections for patient volumes are expected to overrun critical care capabilities, with shortages of PPE, staff, and ventilators dominating discussions in local hospitals and the news media.

We provide a synthesis of the current experience coming from China, Italy and the US and some common sense approaches from past lessons learned. These discussions are prompted by the frequent questions we receive by email and phone. Whenever possible, the statements here are supported by the most recent findings. At the time of this writing, the statement from the Society of Critical Care Medicine (SCCM) has been published addressing many issues related to treatment of ventilated patients.

Recommendations based on SCCM statement:

> Patients with severe CoV-19 should be managed with invasive ventilation following ARDSnet Guidelines.

1. Maintain strict infectious disease precautions.

2. In severe respiratory distress, do NOT delay intubation.

3. In patients with early hypoxemia, consider high flow nasal oxygen. This is controversial, with some concerns regarding environmental contamination. If used, there should be a low threshold for failure and urgent intubation. Some clinicians will elect to avoid high flow nasal cannula.* Environmental controls should be considered with an emphasis on caregiver protection.

4. The use of NIV is associated with a high rate of failure. Because of high failure rate and the possibility of environmental contamination, we suggest avoiding NIV. (If NIV is used a low threshold for failure; e.g., no improvement in 1-2 hours should prompt intubation).* It is recognized that some patients with a COVID diagnosis might benefit from NIV, such as those with neuromuscular disease or COPD exacerbation, particularly if they use NIV in the outpatient setting.

5. Mechanical ventilation should follow the ARDSnet recommendations:
   a. Tidal volumes of 4-8 mL/kg of predicted body weight (volume or pressure control).
   b. CMV (assist–control) is recommended due to often heavy sedation requirements.
   c. Plateau pressure less than 30 cm H_2O.
   d. Low PEEP/FIO_2 Table from ARDSnet.

6. In the face of refractory hypoxemia (PaO_2/FIO_2 < 150) – prone positioning is the first recommended therapy. We acknowledge the manpower needs and increased need for PPE associated with manual proning.

What are the major findings in patients with SARS CoV-2 viral pneumonia requiring mechanical ventilation?

> Patients who require mechanical ventilation are severely ill. The intensity of treatment parallels treatment for any ARDS patient.

The preponderance of evidence is for severe hypoxemic respiratory failure in the most critically ill subjects. Of note, pulmonary compliance appears to be reduced but not to levels typically seen with ARDS. In a recent ESICM presentation, Pesenti reported on 672 patients from Lombardy, Italy.[1] In this cohort, the median PEEP was 14 cm H_2O with the majority of patients managed between 10 and 20 cm H_2O (25%-75% percentile 12 - 15 cm H_2O). The median FIO_2 was 0.55 with the 25%-75% percentiles of 0.45 and 0.70. Nearly 30% of patients required an FIO_2 of 0.70 or greater.

In the recent report from Seattle by Arentz et al,[2] in a series of 21 subjects, more than half had severe ARDS (57%) with a mean PaO_2/FIO_2 at admission of 169 (69-492) and a nadir PaO_2/FIO_2 108 (58-247).

In the Boston experience,[3] almost all patients presented with dyspnea and were intubated on the day of hospital presentation. They had a median PaO_2/FIO_2 of 182, V_D/V_T

These are one area where we are not in complete agreement with the SCCM document.

of 0.45, and compliance of 35 mL/cm H_2O. Patients were managed with established ARDS therapies including low tidal volume ventilation, conservative fluid administration, and prone position in many cases. Overall mortality was 17% and the majority of patients were successfully extubated and discharged from the ICU.

Anecdotally, optimal PEEP is not as high as might be expected with the level of hypoxemia present. Optimum PEEP is often in the range of 8 - 12 cm H_2O.

Reported mortality in mechanically ventilated patients with SARS-CoV-2 varies widely and these reports are flawed on partial datasets. Thus, mortality associated with SARS-CoV-2 is not currently known.

Humidification

> An HMEF or heated humidifier can be used in these subjects.

While heated humidification has advantages, the use of a heat and moisture exchanging filter (HMEF) can provide sufficient humidification while also protecting staff and the environment. These can be standard filters or HEPA filters. Caution: the use of HMEFs increases mechanical deadspace by ~30 mL, which for an average sized adult translates to 0.5 mL/kg and an increase in V_D/V_T of 8%. As V_D/V_T in moderate and severe ARDS typically is ~0.60 and ~0.70, these devices likely will require similar small adjustments in preset V_t to maintain alveolar ventilation.

During SARS-CoV-1 in Canada, following identification of the infection, patients testing positive for SARS were placed on ventilators with heated expiratory filters. The impact on transmission following this change was difficult to measure.

The experience from hospitals in Seattle has been that excess pulmonary secretions were not commonly seen. We do not know if using an HMEF makes an expiratory filter redundant. An expiratory filter may provide additional protection of the environment. CAUTION: Expiratory filter resistance may increase with use of heated humidification and time. Observe the patient for signs of increased expiratory resistance (PEEPi, expiratory flow limitation). There have also been reports of partially occluded or obstructed ETT, more commonly when using an HME. Therapists should triage the type of humidifier used to the needs of the patient. The use of catheters to clean the inside of ETT should also be considered to rescue tubes and reduce the need for bronchoscopy or emergent switching of ETT.

Reports from other cities (New York, Boston, Chicago) hospitals with a significant number of patients diagnosed with SARS CoV-2 report that these patients develop thick, tenacious secretions as the disease progresses. This may be due to viral infection in patients with pre-existing lung disease and/or the development of secondary bacterial infection. In these patients, HME(F)s may become soiled and require frequent changing. Breaking the circuit to change the HME(F) can result in contamination of the environment. When possible, these patients may need to be transitioned to heated humidifiers as these devices become available. Care should be taken in performing secretion clearance maneuvers, as many of these may qualify as aerosol generating procedures.

What about prone position?

> Prone position should be considered with refractory hypoxemia.

Placing patients with severe ARDS into prone position improves ventilation-perfusion matching, reduces lung strain and stress, recruits dorsal atelectatic alveoli, and improves hypoxemia.[4,5] Most important, it reduces mortality[4-6] and is recommended in the treatment of mechanically ventilated patients with severe ARDS.[7]

Prone positioning should be attempted if the patient has refractory hypoxemia to other strategies, such as ARDSnet ventilation, PEEP titration, and neuromuscular blockade. Given the severity of hypoxemia associated with SARS CoV-2, prone position is commonly used in this setting.[3] A typical schedule is prone position for 16-20 hours followed by supine position for 4-8 hours. When the patient is prone, their head should be rotated, and body shifted, every 2 to 4 hours. With persistent refractory hypoxemia when turned supine, return the patient to prone position. Prone position can be used in non-intubated patients as tolerated.[8] This may be beneficial if gas exchange improves. However, because tidal volume is usually not monitored during spontaneous breathing, self-inflicted lung injury is a concern and invasive ventilation should be considered if oxygenation does not improve when prone. Patients with a tracheostomy tube cannot be placed prone.

Complications of prone position include malposition of the endotracheal tube, central venous access line, arterial line, or other lines/drains.[4] These complications can lead to cardiopulmonary arrest if not recognized and corrected immediately. In addition, prone position can lead to significant facial and peri-orbital edema, which is decreased by periodic return to the supine position and placement of ice packs to reduce facial edema. Assessment of skin integrity should be done frequently, as pressure injury from artificial airway securement devices can develop quickly, given the bony structure of the face. This can be mitigated with use of various skin dressings and positioning devices to relieve pressure points.

Teams of clinicians dedicated specifically to placing patients prone have become popular. The multidisciplinary team includes 4 to 5 clinicians including registered nurses, physical therapists, and occupational therapists. As a vital member of this team, the respiratory therapist assumes responsibility to

ensure the endotracheal tube does not become dislodged. Other members of the team control limb movement and placement. The added help of the prone team provides relief to bedside clinicians during times of high acuity. Furthermore, a team consistently working together can have better internal communication and mastery of the task.

Can the SNS stockpile ventilators manage patients with COVID-19?

> The LTV-1200 and the Impact 754 can be used to treat the majority of patients described to date. **(Please see the videos for use at the AARC website.)**

The SNS ventilators include the LTV-1200, the Impact 754 and the LP-10. The LTV-1200 and Impact 754 can deliver the required tidal volumes, FIO_2, and PEEP to maintain the majority of patients based on the current clinical presentation. Both devices have been used to manage ARDS patients during military transport and in disaster operations. Both are capable of delivering a PEEP of 20 cm H_2O and near 100% oxygen. The LTV-1200 is the most common and newest device in the stockpile and we believe will likely be issued first.

The LP-10 is a piston-based home care ventilator with only a

low flow oxygen inlet and the addition of PEEP with an external valve. The LP-10 can only provide volume ventilation. Three factors limit utility of this ventilator for hypoxemic respiratory failure: its limited FIO_2 range, inability to select and maintain a set FIO_2 and it's requirement for an external PEEP valve.

Notes regarding function:

1. The maximum peak flow of the Impact 754 is 60 L/min using a constant flow waveform. The 754 only provides volume ventilation. Patients with high inspiratory flow demands may have flow asynchrony.

2. Tidal volume delivery with the 754 at the low end is improved with the use of external air bypassing the internal compressor.

3. None of the ventilators in the stockpile have an expiratory filter. Placement of an expiratory filter will be important prior to use on infectious patients.

4. All the SNS ventilators have a room air inlet for the compressor and inlet filters should be added to the 754 and the LP-10. The LTV-1200 has an internal filter.

Respiratory therapists should be familiar with the devices which might be provided and triage the ventilators to the needs of individual patients.

In 2014, the CHEST Consensus statement on the care of the critically ill and injured during pandemics and disasters

Settings	Day 1	Day 7
PEEP (cm H_2O)	9.4 ± 3.6 (6-13)	8.1 ± 3.4
FIO_2	0.56 ± 0.19 (0.35-0.75)	0.50 ± 0.17
$\dot{V}_E$ (L/min)	12.9 ± 3.6 (10-18)	13.7 ± 3.8
PIP (cm H_2O)	32 ± 8 (20-40)	33 ± 9
Breathing frequency (b/min)	29 ± 7 (12-35)	30 ± 7

Table 1. *Data from the ARDSnet ARMA trial (reference 10)*

Operating feature	Mandatory Specifications
V_T	50 - 750 mL
PEEP	0 - 20 cm H_2O
Breathing frequency	6 - 35 breaths/min
FIO_2	0.21-0.95
Inspiratory flow	Low < 10 L/min High > 80 L min
Breath type	Volume and pressure control
Control of V_T and f	Separate controls
FDA approved	Pediatric and adult
Monitoring	Measured exhaled V_T
Alarms audible and visual	Disconnect, apnea, high pressure, low source gas pressure

Table 2. *Recommendations from the CHEST Consensus statement. (reference 9)*

developed a list of standard criteria for ventilators to be used in the case of a mass casualty respiratory failure (MCRF) event.[9] This work was based on the ventilator settings used for care of patients with ARDS in the ARDSnet ARMA trial.[10]

Data from the ARDSnet ARMA trial (6 mL/kg vs 12 mL/kg V_T) demonstrated the following settings on day 1 and day 7 along with a range for each variable for day 1 and day 7. (Table 1)

These data provide evidence for some standard functional performance requirements for ventilators stockpiled for use in mass casualty respiratory failure. Assuming predicted body weights of 62–90 kg (males 165– 196 cm tall), ventilators must be capable of delivering V_T of 250 –720 mL (4 – 8 mL/kg). Ventilators that are unable to produce those settings at a minimum are not suitable for MCRF or stockpiling. These ventilator characteristics are shown in the Table 2.

Importantly, in an effort to meet the anticipated need for ventilators based on data from Italy and New York City, the Federal Emergency Management Agency (FEMA) has purchased a number of ventilators from full featured devices to emergency ventilators intended for long-term care or pre-hospital care. Several of these ventilators do not meet the requirements in whole or in part. Similarly, few of the proposed do-it-yourself ventilators and devices produced by individuals novice to the industry, despite the best of intentions, will meet these specifications.

The AARC recommends that any ventilator purchases be made with the requirements of patients with ARDS in mind. Patients with COVID-19 viral pneumonia have severe hypoxemia and high oxygen requirements. Additionally, patients who require mechanical ventilation and survive, require spontaneous breathing modes and effective monitoring and alarms to lead to successful ventilator liberation. The ventilator's ability to deliver a full range of FIO_2, sufficient minute ventilation, PEEP, and inspiratory flow are critical to patient management, patient comfort, and success. In the recent report from Boston, the

	Median (interquartile range)
PaO_2/FIO_2	182 (135-245)
Estimated physiologic deadspace fraction	0.45 (0.38-0.58)
Ventilatory ratio ($\dot{V}_E$ x $PaCO_2$/PBW)	1.25 (1.06 -1.44)
Positive end-expiratory pressure (cm H_2O)	10 (8-12)
Plateau pressure (cm H_2O)	21 (19-26)
Driving pressure (cm H_2O)	11 (9-12)
Lung compliance (mL/cm H_2O)	35 (30-43)
Airway resistance (cm H_2O/L/s)	5 (4-7)

Table 3. *Data extracted from reference 3 (66 ventilated patients with COVID 19).*

mortality rate in mechanically ventilated patients with COVID-19 was 17%. The characteristics of this group of 66 patients at the time of intubation, with respect to pathophysiology are shown here. Of note in this cohort a quarter of subjects received an inhaled pulmonary vasodilator, nearly half were placed in the prone position, only one patient was placed on high flow nasal cannula prior to intubation, and only 2 required ECMO.[3]

Can bilevel ventilators be used for invasive ventilation?

> CPAP machines designed for obstructive sleep apnea cannot be repurposed as ventilators by clinicians. However, bilevel devices are ventilators and can be used for invasive ventilation.

There have been suggestions in the media that CPAP machines designed to treat obstructive sleep apnea can be repurposed as ventilators. This is not something that a respiratory therapist can do and this should not be attempted.

It is possible for bilevel devices, including those used in the hospital and those used in the home, to be used for invasive mechanical ventilation. Some, but not all, bilevel devices are FDA-cleared for use as an invasive ventilator. These ventilators are commonly used for chronic respiratory failure and some sleep disorders.

Bilevel ventilators do not have an active exhalation valve. Of concern is aerosol generation from the leak port. This is a legitimate concern. There are commercially available filters that can be fitted to the leak port. Check with the manufacturer to purchase these for your circuits before using this ventilator type on a patient with COVID-19.

We recommend active humidification when a bilevel ventilator is used for invasive respiratory support. Alternatively, a heat-and-moister exchanger (HME) can be used. If using an HME, ideally an HME-filter is used and this might obviate the need for a filter on the leak port.

On bilevel ventilators, the level of respiratory support is determined by the difference between IPAP and EPAP. This difference is the level of pressure support or pressure control. The level of EPAP (PEEP) can be increased as needed to support hypoxemic respiratory failure, but it is important to remember that IPAP must be increased when EPAP is increased (and vice versa).

FIO_2 can be set directly on some bilevel ventilators. For others, oxygen is titrated into the system. For oxygen titration, follow the instructions of the manufacturer.

As with any ventilator, lung protective ventilation strategies should be used. If the ventilator displays tidal volume, target 6 mL/kg predicted body weight and a driving pressure (IPAP-EPAP) less than 15 cm H_2O. Titrate PEEP appropriately, such

as with the appropriate ARDSnet PEEP table (usually the low PEEP table).

For safety, alarms should be set appropriately when any bilevel ventilator is used. Continuous pulse oximetry should also be used, with alarms set appropriately.

We suggest that use of bilevel ventilators for invasive support should be triaged. Ideally, they should be used for patients who do not have COVID-19, thus freeing critical care ventilators for patients with COVID-19 hypoxemic respiratory failure.

Triage ventilator performance to patient illness

> Use the highest technology equipment for the most severely ill patients.

As with any asset, the ventilators at your disposal should be triaged for use, matching the device capabilities with the severity of patient illness. The patients with the most severe hypoxemia requiring high PEEP and high FIO_2, with reduced compliance, should be triaged to ICU ventilators. Patients requiring ventilation for non-COVID related illness can be managed with portable devices and less sophisticated devices in your inventory. The SNS ventilators can be woven into that matrix which includes the use of anesthesia workstations.

Can I ventilate more than one patient with a single ventilator?

> Do not attempt to ventilate multiple patients with a single ventilator. As a last-ditch effort, an attempt to ventilate 2 subjects with similar compliance might be attempted after approval of local Ethics Committee and/or Institutional Review Board (IRB).

The interest in ventilating multiple patients on a given ventilator has been piqued by well-intended but potentially dangerous internet videos. The first modern descriptions for 4 patients per ventilator were advanced by Neyman et al[11] in 2006 and Paladino[12] in 2008. In each instance Branson, Rubinson and others have cautioned against the use of this technique. At present we recommend that you **DO NOT** attempt to ventilate 4 patients with a single ventilator.[13-15] Since the onset of the COVID-19 pandemic, there have been a number of additional reports of approaches to ventilator splitting.[16-20]

Of note, the jump to 4 patients without considering just 2 patients is nonsensical due to the complexity of this approach. We hope to provide more guidance on the safest possible application of a single ventilator for 2 patients in the near future.

Regarding the 4-patient scenario, the patients would have to be arranged around the ventilator like spokes abound a hub. This positioning moves the patient away from the supplies of oxygen, air, and vacuum at the head of the bed. It also places the patients in close proximity for transfer of other organisms. It cannot be done in separate rooms. One of our concerns is that in attempt to position patients, extra dead space (resulting in hypercarbia) or longer tubing contributing to compressible volume could be dangerous.

We do not find that matching patients by size is relevant, however matching by compliance, driving pressure, PEEP, and FIO_2 are far more important. Patients have to be heavily sedated and paralyzed. Spontaneous breathing by a single patient sensed by the ventilator would set the respiratory frequency for all the others. Worse, the added circuit volume could preclude triggering (note the internet presentations suggest making the ventilator less sensitive) and may cause the patients to share gas between circuits in the absence of one-way valves. Pendelluft between patients is not out of the question resulting in rebreathing, cross infection, and over-distension. The reasons not to ventilate 4 subjects with 1 ventilator are too numerous to mention. An abbreviated list is shown below:

1. The added circuit volume defeats the operational self-test (the test fails). You have to operate the ventilator without a successful test adding to errors in the measurement.

2. Additional external monitoring is required – the ventilator monitors only the average pressures and volume. The system prevents monitoring changes in the individual patients.

3. Even if respiratory mechanics of all 4 patients are the same at initiation, if one becomes sicker, one stays the same, two are getting better, the distribution of gas to each patient is unequal and unmonitored. The sickest patient gets the smallest V_T and the improving patient gets the largest V_T. This was clearly evident in the study by Paladino[4] wherein all four sheep were observed to have episodes of pronounced decreases in PaO_2 and acute hypercapnia likely signifying underventilation resulting from substantial changes in chest mechanics between the animals.

4. Ventilator weaning or ventilator discontinuation is impossible and the patient who is improving has to be switched to a single ventilator. Some ventilators must be available if one patient improves or deteriorates.

5. During airway suctioning of one patient, ventilation of the other patient is interrupted.

6. There are longer term consequences to this approach that paradoxically could worsen the supply of ventilators during a pandemic. Chief among these is that prolonged use (i.e. > 48 hr) of paralytic agents may be associated with ICU acquired weakness that prolongs the need for mechanical ventilation. This becomes particularly worrisome as the median duration of mechanical ventilation in SARS and MERS ranges between 8-31 days.

In addition, the ability to reduce mechanical ventilation duration and ICU length of stay is inextricably related to the ability to perform spontaneous breathing trials and daily sedation interruptions. This process is stymied by having more than one patient tethered to the same ventilator. To address this issue would require changing the ventilator used for the patient(s) who "appear" to be recovering faster and would consume an extraordinary amount of clinician time and logistics in a situation when intensive care resources are under maximal stress.

7. We refute the "it's better than nothing defense," as in a cohort of 4 patients, one of whom may die regardless of maximal efforts, the deterioration in that subject may lead to injury in the other three.

8. We suggest that these videos be removed from the internet as they promote a very inexperienced and cavalier approach to a very complicated issue fraught with patient harm.

9. Before any unconventional approaches like this are used, they MUST be approved by the appropriate Ethics Committees and, in some cases, the Institutional Review Board. Failure to do so could result in severe penalties.

What about using artificial resuscitators or minimal function mechanical ventilators?

> Artificial resuscitators have little utility in caring for the subjects requiring mechanical ventilation in this scenario.

The use of disposable and limited function ventilators unable to control V_T, PEEP, or FIO_2 and those with limited inspiratory flow capabilities (limiting the total rate) are not viable candidates for this illness. Again, the "it's better than nothing" or "these can be used in the least ill patients" may not apply. The least ill patients do not require intubation. Those that require intubation require a ventilator capable of meeting the parameters outlined in the ARDSnet treatment guidelines. Of note, artificial resuscitators are only intended for use as life support when attended one caregiver to one patient. And these devices have been shown to fail without alarm with changes in position.[21]

We have similar concerns with the multitude of potential DIY (Do it yourself) projects and hack challenges to create a simple open source ventilator. Mechanical ventilation in this scenario requires a ventilator capable of managing ARDS including PEEP 10-20 cm H_2O, V_T 300-600 mL and minute ventilation of 10-15 L/min. Failure to meet these requirements will not allow support of the these critically ill patients.[22]

What about an inhaled vasodilator?

> Inhaled vasodilators should not be used routinely. Aerosolized vasodilators should be avoided.

The profound hypoxemia associated with SARS-CoV-2 may respond to an inhaled vasodilator. We agree that **routine** use of an inhaled vasodilator is not supported or warranted. However, in the absence of a response to PEEP, lung recruitment, or prone position (or a patient unable to be proned) an inhaled vasodilator might be considered for refractory hypoxemia. The study from Seattle used aerosolized vasodilators in several patients.[2] Given the mode of transmission of the virus, the use of an aerosolized vasodilator might be unwise. Additionally, the requirement for an expiratory filter to prevent accumulation of aerosol in the expiratory valve will require breaking the circuit to change at predetermined intervals. In the current environment, changing filters may result in loss of lung recruitment as well as result in unnecessary exposure of the caregivers. The use of inhaled nitric oxide could be given a short trial. We suggest this be a short trial with pre-established criteria for continued used or discontinuation. We also look forward to improved access and reduced costs for this therapy in the midst of this pandemic.

Aerosol therapy – nebulizers or pressurized metered dose inhalers?

The use of a nebulizer may increase the transfer of particles into the environment and decrease the life of expiratory circuit filters. If a nebulizer must be used during mechanical ventilation, a closed system that does not break the circuit is desirable. The use of pMDIs to deliver bronchodilators may be more prudent. However, there is no role for inhaled bronchodilators in patients with COVID-19 unless the patent has co-morbid asthma or COPD.

Avoidance of the use of nebulizers during the COVID-19 pandemic has lead to a shortable of pMDI. Inhaled bronchodilators should be limited to only patients with proven benefit. Note that the presence of an endotracheal tube or a diagnosis of COVID-19 alone are not indications for inhaled bronchodilator therapy.

Non-ventilated patients

Much of the discussion and concern during this pandemic is associated with mechanically ventilated patients. It is important to remember that standard oxygen therapy has been indicated in over 75% of hospitalized subjects.

Recommendations from the SCCM task force

Ventilation	
In adults with COVID-19, we suggest starting supplemental oxygen if the peripheral oxygen saturation (SPO_2) is < 92%, and **recommend** starting supplemental oxygen if SpO_2 is < 90%	Weak Strong
In adults with COVID-19 and **acute hypoxemic respiratory failure on oxygen**, we **recommend** that SpO_2 be maintained no higher than 96%.	Strong
For adults with COVID-19 and **acute hypoxemic respiratory failure** despite conventional oxygen therapy, we **suggest using** HFNC over conventional oxygen therapy.	Weak
In adults with COVID-19 and **acute hypoxemic respiratory failure**, we **suggest** using HFNC over NIPPV.	Weak
In adults with COVID-19 and **acute hypoxemic respiratory failure**, if HFNC is not available and there is no urgent indication for endotracheal intubation, we **suggest** a trial of NIPPV with close monitoring and short-interval assessment for worsening of respiratory failure.	Weak
We were not able to make a recommendation regarding the use of helmet NIPPV compared with mask NIPPV. It is an option, but we are not certain about its safety or efficacy in COVID-19.	No Recommendation
In adults with COVID-19 receiving NIPPV or HFNC, we **recommend** close monitoring for worsening of respiratory status, and early intubation in a controlled setting if worsening occurs.	Best practice statement
In mechanically ventilated adults with COVID-19 and ARDS, we **recommend** using low tidal volume (Vt) ventilation (Vt 4-8 mL/kg of predicted body weight), over higher tidal volumes (Vt>8 mL/kg).	Strong
For mechanically ventilated adults with COVID-19 and ARDS, we **recommend** targeting plateau pressures (Pplat) of < 30 cm H_2O.	Strong
For mechanically ventilated adults with COVID-19 and moderate to severe ARDS, we **suggest** using a higher PEEP strategy, over a lower PEEP strategy. **Remarks**: If using a higher PEEP strategy (i.e., PEEP > 10 cm H_2O), clinicians should monitor patients for barotrauma.	Strong

For mechanically ventilated adults with COVID-19 and ARDS, we **suggest** using a conservative fluid strategy over a liberal fluid strategy.	Weak
For mechanically ventilated adults with COVID-19 and **moderate to severe ARDS**, we **suggest** prone ventilation for **12 to 16 hours**, over no prone ventilation.	Weak
For mechanically ventilated adults with COVID-19 and **moderate to severe ARDS**: We **suggest** using, as needed, intermittent boluses of neuromuscular blocking agents (NMBA), over continuous NMBA infusion, to facilitate protective lung ventilation.	Weak
In the event of persistent ventilator dyssynchrony, the need for ongoing deep sedation, prone ventilation, or persistently high plateau pressures, we **suggest** using a continuous NMBA infusion for up to 48 hours.	Weak
In mechanically ventilated adults with COVID-19 ARDS, we **recommend against** the routine use of inhaled nitric oxide.	Weak
In mechanically ventilated adults with COVID-19, severe ARDS and hypoxemia despite optimizing ventilation and other rescue strategies, we **suggest** a trial of inhaled pulmonary vasodilator as a rescue therapy; if no rapid improvement in oxygenation is observed, the treatment should be tapered off.	Weak
For mechanically ventilated adults with COVID-19 and hypoxemia despite optimizing ventilation, we **suggest** using recruitment maneuvers, over not using recruitment maneuvers.	Weak
If recruitment maneuvers are used, we **recommend against** using staircase (incremental PEEP) recruitment maneuvers.	Strong
In mechanically ventilated adults with COVID-19 and refractory hypoxemia despite optimizing ventilation, use of rescue therapies, and proning, we suggest using **venovenous** (VV) ECMO if available, or referring the patient to an ECMO center. **Remark:** Due to the resource-intensive nature of ECMO, and the need for experienced centers and healthcare workers, and infrastructure, ECMO should only be considered in carefully selected patients with COVID-19 and severe ARDS.	Weak

Authored by:

Richard D Branson MSc RRT FAARC – Editor in Chief, Respiratory Care; University of Cincinnati

Dean R Hess PhD RRT FAARC – Managing Editor, Respiratory Care

Rich Kallet MSc RRT FAARC

Carolyn LaVita MHA, RRT – Respiratory Care; Massachusetts General Hospital, Boston, MA

Timothy Myers MBA, RRT-NPS, FAARC – Chief Business Officer, AARC

Lewis Rubinson PhD MD - Chief Medical Officer, Morristown Medical Center, Morristown, NJ

Shawna Strickland PhD, RRT-ACCS, FAARC – Associate Executive Director, AARC

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