

APSF/ASA Guidance on Purposing Anesthesia Machines as ICU Ventilators

Anesthesia machines are equipped with ventilators that in many cases are capable of providing life-sustaining mechanical ventilation to patients with respiratory failure. They are used for this purpose every day in the operating room. FDA approved labeling does not provide for using anesthesia ventilators for long term ventilatory support.

Nevertheless, anesthesia ventilators are an obvious first-line backup during the COVID-19 pandemic when there are not sufficient ICU ventilators to meet the patient care needs. Local resources and constraints will impact how this solution can best be implemented. Anesthesia machines not currently being used may be located in your own hospital operating rooms, NORA locations, at nearby ambulatory surgery centers, nearby office-based surgery practices, and through your anesthesia equipment distributors. Guidance is available from the manufacturers, but it may not convey all of the clinical considerations. Anesthesia professionals will be needed to put these machines into service and to manage them while in use. Safe and effective use requires an understanding of the capabilities of the machines available, the differences between anesthesia machines and ICU ventilators, and how to set anesthesia machine controls to mimic ICU-type ventilation strategies.

This document is intended to provide guidance on using anesthesia machines safely and effectively as ICU ventilators. Detailed information is provided below and a [quick reference guide](#) is available for downloading. The quick reference guide is intended to be a bedside tool and includes a suggested schedule for monitoring the effectiveness and safety of the anesthesia ventilator.

ASA is working with component societies to develop an inventory of local resources with the goal of moving machines to the locations where they are most needed.

(NOTE: Local conditions will likely dictate modifications to the recommendations provided. This document is intended to provide reference information that empowers caregivers at the bedside to make the best decisions possible to provide safe and effective care.)



For more information and related documents, visit asahq.org/ventilators

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EDUCATIONAL MATERIAL ON CLINICAL MANAGEMENT OF CRITICALLY ILL PATIENTS WITH COVID 19

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Key Points to Consider in Preparing to Use Anesthesia Machines as ICU Ventilators

GENERAL TOPICS

- **IS THIS USE OF ANESTHESIA MACHINES AS ICU VENTILATORS APPROVED BY FDA AND MANUFACTURERS? (UPDATED APRIL 13, 2020)**

The FDA has temporarily approved the use of anesthesia machines as ICU ventilators.

- <https://www.fda.gov/medical-devices/letters-health-care-providers/ventilator-supply-mitigation-strategies-letter-health-care-providers>
- FDA ENFORCEMENT POLICIES FOR VENTILATORS DURING COVID-19: <https://www.fda.gov/media/136318/download>

GE, Draeger, Mindray, and Getinge have released guidance documents on this off label use of their machines. These guidance documents have useful recommendations for the long term use of these machines as ICU ventilators.

- GE HEALTHCARE: 24x7 phone support (800) 345-2700
 - GENERAL: <https://www.gehealthcare.com/corporate/covid-19>
 - ANESTHESIA MACHINES: <https://www.gehealthcare.com/products/Anesthesia-Delivery-Systems-User-Resources>
 - LETTER: <https://www.gehealthcare.com/-/jssmedia/3c655c83bd6b427e9824994c12be0da5.pdf?la=en-us>
- DRAEGER Medical: (800) 437-2437
 - GENERAL: https://www.draeger.com/en-us_us/Home/novel-coronavirus-outbreak#anesthesia
 - LETTER: <https://www.draeger.com/Library/Content/Customer-Letter-Covid19-Usage-of-Anesthesia-devices-for-Long-Term-Ventilation.pdf>
- MINDRAY: (800) 288-2121 or (877) 913-9663
 - <https://www.mindraynorthamerica.com/covid-19-response/>
- GETINGE
 - https://www.getinge.com/dam/hospital/documents/marketing-sales/customer-letters/english/mcv00103387_reva_covid-19_customer_letter_long_term_ventilation_with_flow-en-us.pdf

- **WHO SHOULD MANAGE THE MACHINE?**

An anesthesia professional should be immediately available at all times (24/7/365) to manage the use of the anesthesia machine as an ICU ventilator. Intensivists, ICU nurses and respiratory therapists are not trained to manage anesthesia machines, and are likely to be overextended and stressed. Consultation with intensivists on the preferred ventilation strategy is of course

desirable. Respiratory therapists are essential in the management of multiple critically ill patients and long-term ventilation. Work with them on hospital policies for placement and replacement of breathing circuit filters and other disposable components. An anesthesia professional needs to be immediately available for consultation, and to “round” on these anesthesia machines at least every hour. Anesthesia machines are not protected against non-authorized users; policy and signs should warn non-authorized users about changing anesthesia machine settings.

- **ARE ALL PATIENTS WITH RESPIRATORY FAILURE CANDIDATES FOR AN ANESTHESIA VENTILATOR? (UPDATED APRIL 7, 2020)**

While the specifications of most anesthesia ventilators make them suitable to support patients with respiratory failure, there are considerations that could influence which patients are selected. If the patient population and available devices allow for patient triage to different devices, here are some thoughts to guide patient triage.

- Anesthesia ventilators allow for rebreathing of exhaled gas through the ventilator circuit. Consider using anesthesia machines as ICU ventilators on patients who are not COVID-19 positive to reduce the risk of the rebreathing system becoming a COVID-19 vector. Breathing system filters are however recommended for all patients. Anesthesia machines require more monitoring than do ICU ventilators and room access for non-COVID patients is easier.

- **WHERE SHOULD THE MACHINES BE USED? OR or ICU? (UPDATED APRIL 14, 2020)**

Ongoing ICU level patient care is best done in an intensive care unit but the local resources will likely dictate where the anesthesia machines will be deployed.

- ICU Rooms: At a minimum, the room requires space to accommodate the machine and sources of high pressure air and oxygen. **Scavenging is not required or necessary if appropriate viral filters are placed on the circuits and inhaled anesthetics are not used.** A scavenger connection can be made to any hospital suction outlet, but connectors may not be identical to those in the OR and different tubing or adapters may be required to make the connection in the ICU. ICUs have fewer electrical outlets than do operating rooms, and there is potential for electrical failure of multiple devices, including the anesthesia machine, if circuits are overloaded. See section on machine setup below.
- Operating Rooms: These rooms should be available in the absence of elective surgery and are appealing as isolation rooms especially if negative pressure capability is present. The anesthesia machines will be readily available for use and connected to gas supplies as well as networked for recording data to the EMR. ORs may be the only option if the ICUs become filled but have patient care drawbacks. Alarms will not be audible outside of the operating room and will need to be set to maximum volume. A caregiver will need to be continuously present in the

room with the doors closed and it may be challenging to reproduce all of the ICU care resources in that location.

- PACU beds and other hospital rooms: PACUs are typically open with increased noise levels and the potential to spread infectious agents. Other hospital rooms may be more desirable. Physical space and sources of high pressure air and oxygen are the only requirements for using the anesthesia machine as a ventilator. Wherever these machines are deployed, there will need to be an anesthesia professional immediately available and following a monitoring schedule to insure safe use.

● **IF WE HAVE A CHOICE, DOES IT MATTER WHICH ANESTHESIA MACHINE WE USE? (UPDATED MAY 7, 2020)**

There are differences in the mechanical ventilation capabilities of different anesthesia machines. In general, newer machines have more modes of ventilation, more flexible settings and specifications similar to ICU ventilators (Table). Anesthesia ventilators with **compliance compensation and tidal volume delivery unaffected by fresh gas flow** are preferred, as they provide more consistent tidal volume delivery and more accurate monitoring. Anesthesia machines obtained from ambulatory surgery centers or office-based practices may be the least suitable for this purpose; however, they might be used to fill-in for the more capable anesthesia machines that have been moved to the ICU.

TABLE OF VENTILATOR SPECIFICATIONS BY ANESTHESIA MACHINE

Anesthesia machine model	Ventilator drive	Pmax	RR max	PEEP max	Vt / MV max	Spirometry/ Compliance/ Sensing	Autoclavable?
Draeger Apollo	E - Piston	70	100	20	1400 / 50	Y/Y/Y	Y
Draeger Fabius or Tiro	E - Piston	70	60	20	1400 / 25	N/Y/Y	Y
Draeger Perseus	E - Blower	80	100	35	2000/ 40	Y/Y/Y	Y
GE Aisys	P - Bellows	100	100	30	1500 / 120	Y/Y/Y	Y
GE Aisys C ²	P - Bellows	100	100	30	1500 / 120	Y/Y/Y	Y
GE Avance	P - Bellows	100	100	30	1500 / 120	Y/Y/Y	Y
GE Avance C ²	P - Bellows	100	100	30	1500 / 120	Y/Y/Y	Y
GE Carestation 600 series	P - Bellows	100	100	30	1500 / 120	Y/Y/Y	Y
Getinge Flow-i	P - Reflector	80	100	50		Y/Y/Y	Y
Mindray A7 Advantage	P-Bellows	100	100	30	1500 / 30	Y/Y/Y	Y
Mindray A5 Advantage	P-Bellows	100	100	30	1500 / 30	Y/Y/Y	Y
Mindray A4 Advantage	P-Bellows	100	100	30	1500 / 30	N/Y/Y	Y

P-Pneumatic; E-Electrical

Autoclavable? - All machines have breathing systems that can be autoclaved in whole or in part. Manufacturer recommendations should be reviewed for specific autoclaving procedures and lists of components that need to be cleaned separately.

The most capable anesthesia machines should be utilized first, and it is preferable to use one model rather than introduce a mix into the ICU. If used to ventilate COVID-19 positive patients, select machines whose breathing systems and ventilators can be sterilized. Start with an anesthesia machine whose ventilator can provide SIMV + PS using either volume and pressure targeted modes of ventilation mixed with pressure support. Then, use other models with similar capabilities. Lastly, realize that the ventilation capabilities of most anesthesia machines, even those with limited ventilation modes and no PS capability, should be sufficient as a life saving intervention for the majority of patients. Respiratory monitoring is also important including pressure and flow monitoring with alarms. Real time spirometry (Flow-Volume and Pressure-Volume loops) is quite useful when caring for patients with respiratory failure, and for diagnosing leaks around the endotracheal tube and increased resistance through the airway HMEF.

Oxygen utilization can be a factor when selecting anesthesia machine ventilators and managing the ventilation modes. In general, pneumatically powered ventilators consume more oxygen than electrically powered ones but modifications will be described for conserving oxygen with all ventilator designs.

- **DOCUMENTATION OF VENTILATION PARAMETERS**

In many hospitals, anesthesia machines are connected to a network to automate documentation of ventilation parameters to the patient record. Continuing that documentation is easy if the machines remain in the operating room. If moved to another location in the hospital, it may be possible to restore the network connection for automated documentation or intermittent manual documentation may be needed. If manual documentation is needed, a template should be used for documentation.

EQUIPMENT CONSIDERATIONS

- **MACHINE SETUP (UPDATED APRIL 9, 2020)**

Setting up the machine will require

- Removal of monitors and computers that are mounted to the anesthesia machine prior to its use in an ICU.
- Connections to pressurized oxygen and air, either to hospital pipeline or large G or H cylinders. Backup oxygen and air cylinders.
- Removal or drainage of all vaporizers.
- Removal of nitrous oxide cylinder and pipeline hoses
- Possibly modifying default ventilator parameters and alarm settings (e.g., PEEP level, alarm volume, minute ventilation and airway pressure alarms, etc.) to match those of ICU ventilators

- Scavenger system connection
 - Scavenging is not required if inhalation agent delivery is not planned and the gas analyzer sampling line is filtered. If the scavenging system is not connected to suction, then either 1) it should be disconnected from hoses coming from the breathing system and ventilator, or 2) the scavenger reservoir bag should be removed if it is a closed-scavenger system. Either of these interventions will prevent high pressures in the scavenger system which would cause gas to back up into the breathing system resulting in high airway pressures and unintended PEEP at the airway.
 - Scavenging is required if inhalation agents may be used for sedation and any suction supply is acceptable. Since the OR often uses WAGD connectors, the tubing used in the OR may not work in the ICU and alternate tubing or connectors may be required.
- Changing the drive gas if the anesthesia ventilator contains a bellows. 100% oxygen is the standard drive gas for a bellows-type ventilator, and it is consumed at approximately the minute ventilation (which is significantly more than the fresh gas oxygen consumption). If oxygen supplies are limited or being conserved, modifications can be made on some anesthesia machines to use compressed air as the drive gas. Such modifications can be done but it may require a few hours to complete by a trained clinical engineer following the manufacturer's instructions.
 - To convert a GE bellows ventilator from 100% O₂ to compressed Air:

Technical Reference Manual Sections:

● Aisys CS2	Section 9.27 Change drive gas
● Avance CS2	Section 9.27 Change drive gas
● Carestation 6xx	Section Change drive gas
● Aespire View	Section 9.28 Change drive gas

CAUTION: If you change the drive gas, you must also change the drive gas selection on the ventilator service setup screen. Refer to Section 4 of the ventilator Technical Reference manual. If the drive gas selection and the actual drive gas do not agree, volumes will not be correct.
 - To convert a Mindray bellows ventilator from 100% O₂ to compressed Air:
 - <https://www.mindraynorthamerica.com/wp-content/uploads/2020/03/1659B-Considerations-for-MR-Anes-Sys-used-for-Vent-during-COVID-19-Air-Drive-Gas-Addendum.pdf>
- A breathing circuit with reservoir bag and high quality viral filters on the airway and expiratory limb of the circuit. Maintaining a stock of filters and breathing circuits will be a challenge and should be a constant focus. Filters will serve several functions:

- Protect the anesthesia machine from internal contamination: Two filters in the expiratory gas path will multiply the effectiveness of each one.
- Filter any gas removed from the circuit for gas concentration analysis: The airway mounted filter may have a sampling port on the circuit side of the filter.
- Protect the environment when the circuit is disconnected: If the circuit is disconnected from the machine side of the filter, any gas exhaled into the environment will be filtered. If the circuit is disconnected on the patient side of the filter, it is recommended that the endotracheal tube be clamped during inspiration before disconnecting to preserve lung volume and prevent room contamination .

THE TYPE OF FILTER SELECTED FOR AN ANESTHESIA MACHINE USED AS AN ICU VENTILATOR IS IMPORTANT FOR EFFICACY AND HUMIDITY CONCERNS: Real world experience has shown that the airway filters tend to become obstructed quickly, requiring frequent replacement. This is probably due to humidity accumulation in the circuit. To minimize filter clogging and the need to change filters frequently, fresh gas flows in excess of minute ventilation are typically required. The existing FAQs on filter use with anesthesia machines from APSF (see [FAQ on Anesthesia Machine Use, Protection, and Decontamination During the COVID-19 Pandemic](#)) recommend that a heat and moisture exchange filter (HMEF) should be placed at the endotracheal tube connection to the breathing circuit, and a second HMEF or filter should be placed on the expiratory hose where it connects to the anesthesia machine. Use of an airway HMEF is intended to preserve humidity in the lungs during long term ventilation. HMEs may be contributing to the humidity problem and frequent clogging since they are inherently designed to hold moisture. Viral filters are available that do not have the heat and moisture exchange properties and may be a useful alternative. These types of viral filters are commonly used on the exhaust port of ICU ventilators and may be available from regular stock, although they do impose significant dead space and may not have a sampling port for gas analysis. Note that Draeger, Medtronic and Pall (and others) all produce quality viral filters with sampling ports for gas analysis.

- A backup manual resuscitator (bag-valve-mask) with expiratory port filter that is available at all times for backup ventilation. Note that In some anesthesia ventilator failure modes, manual ventilation using the anesthesia machine may still function properly.
- Respiratory gas monitor(s) for inspired oxygen and inspired/exhaled carbon dioxide, either internal or external to the machine

- MACHINES THAT ARE NEW TO YOUR ORGANIZATION: If a machine has been acquired it will need to be checked by an in house biomedical technician. It may or may not be a device that the in-house technician is familiar with. [ECRI has guidance](#) for required essential steps if time and resources are constrained.
- **MANAGING THE SELF TEST (UPDATED APRIL 2, 2020)**
 Most modern anesthesia machines have startup-test procedures to be performed before use that should be repeated every 24 hours to ensure proper function. The patient cannot be ventilated with the anesthesia machine during the startup-test, even in manual mode, so alternative means of ventilation are necessary during this time. Although it is not considered ideal, guidance from manufacturers during this crisis allows for a startup-test interval up to 72 hours. Power to the machine should be cycled between every patient and no longer than once every 72 hours. Refer to this [Startup-Test Checklist](#) for step-by-step guidance.
- **DELIVERING A DESIRED INSPIRED OXYGEN CONCENTRATION**
 - Due to rebreathing in a circle system, the inspired oxygen concentration may be significantly lower than the fresh gas concentration. For this reason, **inspired oxygen concentration must be monitored**. Rebreathing increases progressively as fresh gas flow is reduced below minute ventilation.
 - On some anesthesia machines, the oxygen concentration of the fresh gas can be set directly, along with the total flow.
 - On other anesthesia machines, the flows of oxygen and air are set and the fresh gas oxygen concentration must be calculated. The following table is a general guide to ratios of oxygen and air flow and the resulting oxygen concentration that will be delivered to the circuit.

Desired FiO ₂	Oxygen to Air Ratio	Oxygen flow for 5 L/min total	Air flow for 5 L/min total
21%	0 to 1	0.0	5.0
25%	0.06 to 1	0.3	4.7
30%	0.13 to 1	0.6	4.4
35%	0.2 to 1	0.8	4.2
40%	0.3 to 1	1.2	3.8
50%	0.6 to 1	1.9	3.1
60%	1 to 1	2.5	2.5
80%	3 to 1	3.8	1.3
100%	1 to 0	5.0	0.0

- Regardless of how the fresh gas oxygen concentration is set, the resulting patient inspired oxygen concentration will depend upon the fresh gas flow and amount of rebreathing. Fresh gas oxygen concentration may require adjustment to maintain the desired inspired oxygen concentration.
- **TOTAL FRESH GAS FLOW SETTINGS (UPDATED MAY 7, 2020)**

The ability to change fresh gas flow and alter the amount of exhaled gas rebreathed is the key feature distinguishing an anesthesia ventilator from an ICU ventilator. In general, if the fresh gas flow exceeds minute ventilation, there is little to no rebreathing; although fresh gas flows as high as 1.5 times minute ventilation may be needed on some anesthesia machines. As fresh gas flow is reduced, progressively more exhaled gas is rebreathed. Rebreathing has the advantage of conserving oxygen and anesthetic agent but utilizes CO₂ absorbent and generates heat and humidity.

THE EXPERIENCE TO DATE IS CLEAR THAT WHEN AN ANESTHESIA MACHINE IS USED AS AN ICU VENTILATOR, LOW FRESH GAS FLOW LEADS TO EXCESSIVE HUMIDITY IN THE CIRCUIT, CLOGGING OF FILTERS, AND THE NEED TO CHANGE CO₂ ABSORBENT FREQUENTLY.

- **Initially, set fresh gas flow to equal minute ventilation - about 6-8 Liters per minute in adult patients**
- **Monitor the circuit for excess humidity and increase fresh gas flow as needed to prevent humidity from accumulating. Note that water in the circuit will not disappear by changing fresh gas flow and will need to be emptied. [See Instructions Below](#)**
- **CO₂ absorbent should be used slowly, if at all, but should be left in place**
- **Monitor inspired CO₂ and change absorbent if indicator changes and inspired CO₂ increases (e.g., above 5 mmHg)**
- **If there is no condensation in the inspiratory hose, use an HMEF at the airway to insure that adequate humidity is maintained in the lungs**
- **Use a high-quality viral filter at the end of the expiratory limb**

The goal of these recommendations is to reduce or eliminate rebreathing of exhaled gas. Absorption of exhaled carbon dioxide generates moisture and utilizes the CO₂ absorbent. Eliminating rebreathing prevents the accumulation of excess moisture in the circuit and the need to replace the CO₂ absorbent. Adult patients will typically require a minute ventilation of 6 to 8 liters per minute to achieve normocapnia. Once the fresh gas flow is increased to the point that there is no rebreathing (typically 1 to 1.5 times minute ventilation), increasing fresh gas flow further provides no advantage and wastes compressed gas.

Since fresh gas entering the circuit has no humidity, a heat and moisture exchange filter (HMEF) may be necessary at the airway to preserve the humidity in the lungs. Condensate inside the inspiratory hose indicates that the relative humidity of inspired gas is greater than 100%, in which case a filter without an incorporated HME can be used at the airway. This may reduce the rate at which the airway filter becomes clogged. CO₂ absorbent should be left in place to reduce the internal volume of the breathing circuit and protect the patient from hypercarbia if FGF is reduced, or does not completely prevent rebreathing. It is possible that there may be a small amount of rebreathing and utilization of absorbent. Changing absorbent when the inspired CO₂ reaches 5 mmHg will minimize waste.

- **STRATEGIES FOR CONSERVING OXYGEN (UPDATED APRIL 13, 2020)**

Inadequate oxygen supply has become a concern due to the high demand for oxygen when treating patients with COVID-19 related respiratory failure. Oxygen is a primary therapeutic intervention delivered either during mechanical ventilation or as a supplement via helmet, mask or nasal cannula. There are three possible reasons why the supply of oxygen can be inadequate:

- Not enough oxygen in the supply source - Despite the concern for insufficient oxygen supply, production and delivery of oxygen does not seem to be a common problem. Inability to treat patients because there is no oxygen is not being reported.
- Freezing of the oxygen vaporizer(s) at the central supply - Since bulk oxygen is supplied and stored in liquid form, it must be vaporized before being delivered to the patient. Vaporizers can become coated in ice as heat is taken from the air around the vaporizer. Ice on the vaporizer will impede heat transfer and slow the rate at which liquid oxygen is converted to gas. Facility engineers should inspect vaporizers to determine if icing is the problem, and apply external heat to restore vaporizer function.
- Insufficient capacity of supply lines - If too many devices requiring oxygen are connected to the same branch of the oxygen pipeline, the pressure in the lines may fall below the minimum required level. The ability of the supply lines to maintain pressure depends upon the diameter of the supply piping, the length of the supply lines, the number of oxygen outlets on a single branch and the oxygen consumption of the devices attached. (A useful discussion on the number of ventilators that can be connected to a supply line can be found at: <https://www.jointcommission.org/-/media/tjc/documents/resources/patient-safety-topics/infection-prevention-and-hai/covid19/kp-nfs-kaiser-fspde-medical-air-and-oxygen-capacity-pub-20200329.pdf>). **Check with facility managers for advice on the piping and flow capabilities within the institution.**

Strategies can be employed that will reduce oxygen utilization substantially when using an anesthesia ventilator. Without modification, some anesthesia machines can use 10-12 liters per minute or more of oxygen, compared to 7-10 liters per minute by an ICU ventilator. Options to conserve oxygen include:

- Using an electrically-powered anesthesia ventilator (currently, only made by Draeger): These ventilators do not consume any oxygen to develop pressure and flow; oxygen consumption equals the oxygen fresh gas flow rate.
 - Converting the bellows ventilator (typically powered by compressed oxygen) to use compressed air as the drive gas.
 - GE Healthcare and Mindray North America have documented procedures for converting any of their anesthesia ventilator models to compressed air. This can be done by a qualified clinical engineer in less than an hour. Anesthesia techs and anesthesia clinicians will not typically have the training or documentation to perform this conversion. Obtain detailed conversion instructions from the manufacturers' web sites, referenced above.
 - Reduce fresh gas flow below minute ventilation in increments of 500 mls/min but be vigilant for accumulation of humidity. It should be apparent in 1 to 2 hours if humidity is accumulating in the circuit or not and fresh gas flow can be adjusted up or down accordingly.
- **HUMIDIFICATION CONSIDERATIONS (UPDATED May 7, 2020)**

Compressed gases that enter the breathing circuit have 0% humidity. Not humidifying this gas can dry mucus and other airway secretions leading to mucus plugging, and can injure lung epithelium in the long-term. During anesthesia care, heat and moisture exchangers (HMEs) are commonly used to maintain humidity in the lungs. During long-term ventilation, humidity buildup in the breathing circuit can become a problem, leading to obstruction of the HME.

 - At recommended fresh gas flows, at or above minute ventilation, maintaining adequate humidity in the lungs may require use of a heat and moisture exchanger (HME). HMEFs also contain filters and are recommended.
 - If active humidification is used with high fresh gas flows, you WILL experience problems with ventilation and monitoring that will need to be managed. Active humidification is discouraged by most manufacturers, and should not be necessary.
 - At lower fresh gas flows, significant amounts of condensate can accumulate within the breathing system and disposable tubing. Anesthesia machines are not designed to handle large amounts of condensed water within the breathing system. It can increase resistance to flow through the system, interfere with sensors (such as flow sensors and respiratory gas analyzers), and even short-circuit electronics. Heated breathing systems prevent some of this condensation. Condensers and water traps can be added to some breathing systems to help collect condensed water.

- Accumulated fluid in the absorbent canister or condensor should be free of pathogens and can be drained. Accumulated fluid in the breathing circuit (typically expiratory tubing) may be contaminated. If the fluid interferes with ventilation, it must be removed. Options include emptying the fluid from any water traps or circuit tubing into a container while wearing PPE, or replacing the circuit. The patient may need to be ventilated by another method (second ventilator or manual resuscitation system) if the circuit needs to be opened to drain accumulated water.
- **MONITORING VENTILATION (UPDATED MAY 7, 2020)**

While anesthesia professionals are trained to monitor ventilation during operative cases, there are additional considerations due to the use of extra filters in the breathing circuit, the accumulation of condensed water over time, and the potential for aerosolizing COVID-19 virus.

 - Baseline monitored parameters (Pressure, Flow, Volume, Minute ventilation) should be recorded when therapy is initiated. If spirometry is available, the baseline reference loops should be saved for later comparison.
 - One problem with airway filters is that the resistance through them increases when they become wet (especially electrostatic-type filters) or filled with airway secretions. Increased airway pressure is a late sign of this problem because pressure is sensed upstream of the airway HMEF. However, rule-out an obstructed airway filter in the event of a high airway pressure alarm. Impeded expiratory flow is an earlier indication of a partially obstructed airway filter. It should be looked for by comparing expiratory flow tracings and flow-volume loops to baseline recordings. Impeded expiratory flow is indicated by a decrease in peak expiratory flow or a prolongation of expiratory flow that can be observed on a flow tracing or flow-volume loop. There may also be a slight delay or slurring of the expiratory capnogram.
 - When airway suctioning is needed a closed system is desirable to prevent viral spread. However, using closed airway suction during mechanical ventilation with an anesthesia machine can result in loss of PEEP, negative pressure in the breathing circuit, and in some cases ventilator malfunction. Limiting the suction pressure and the duration of suctioning should decrease the chance of these problems. Alternatively, changing to manual ventilation with the APL set at least to the level of PEEP, at high fresh gas flows should prevent a decrease in airway pressure below PEEP.
 - Condensed water buildup in breathing circuit hoses and dependent parts of the breathing system may cause oscillations in the pressure and flow waveforms, as gases bubble past the fluid obstructions. Suggestions for managing accumulated water in the breathing circuit can be found here. Once water has been removed from the circuit, increase fresh gas flow to prevent water from accumulating again.

- Leak around the endotracheal tube cuff is a hazard in the COVID-19 patient because of resulting aerosolization. With a leak around the endotracheal, the measured exhaled tidal volume will be significantly lower than the measured inhaled tidal volume, and the flow-volume loop will not close. At low fresh gas flows, the bellows will not totally reinflate on exhalation when there is a significant leak around the endotracheal tube cuff (on a Draeger machine with a piston or turbine ventilator, the reservoir bag will progressively deflate).
 - Flow sensors can become increasingly less accurate over time following recalibration during the startup-test. For machines reporting both inspiratory and expiratory tidal volumes, a gradual increase in the difference between inspired and exhaled measurements may indicate that a startup-test is needed to recalibrate the breathing system flow sensors.
 - Especially during pressure-control ventilation with an oxygen driven bellows, an intermittent low oxygen pressure alarm occurring on inspiration indicates inadequate oxygen supply pressure. This can occur when there is high demand on the central oxygen pipeline system during times of high use by multiple ventilators and flowmeters in the same area.
- **PROVIDING POTENT ANESTHETIC AGENTS (UPDATED APRIL 2, 2020)**

Anesthesia machines have the capability of providing inhaled anesthetics for sedation during long-term care. While this might be an attractive option if intravenous sedatives are in short supply, it is not generally recommended when the machines are used as ICU ventilators for the following reasons:

 - Inhaled anesthetics have profound physiologic effects that can have a significant negative impact on critically ill patients
 - Critical care nurses and intensivists are generally not familiar with dosing or monitoring the effects of these drugs
 - Scavenging of exhaled gas is required when delivering inhaled anesthetics and may not be readily available outside of the operating room
 - High fresh gas flows needed to prevent humidity from accumulating in the circuit will result in high anesthetic consumption and the need to frequently refill the vaporizer. Most of this anesthetic is vented to the atmosphere as waste gas, unabsorbed by the patient.
 - Long term sedation with inhaled anesthetics is not a common practice in the United States although it has been used in other countries especially Europe for many years.

These considerations notwithstanding, if intravenous sedatives need to be rationed, it is possible to sedate patients being ventilated with an anesthesia machine by delivering inhaled anesthetics. Considerations for maximizing the safety and effectiveness of inhaled anesthetics when used for ICU sedation can be found in the document entitled: [ASA/APSF Guidance for Use of Volatile Anesthetic for Sedation of ICU Patients](#)

- **CLEANING THE MACHINE BETWEEN PATIENTS**
(UPDATED APRIL 13, 2020)

- If viral filters have been used as directed, there should be little increased risk of passing COVID-19 virus to a subsequent patient via the anesthesia machine. Usual hospital procedures for cleaning anesthesia machines between patients should then be followed including wiping of external surfaces and replacing disposables.
- CO2 absorbent does not necessarily need to be replaced between patients. If viral filters have been used as directed, there should not be any contamination of the CO2 absorbent. Since it is a readily replaced disposable, some institutions are choosing to replace absorbent after a patient suspected, or documented to be, COVID +. There is no evidence that absorbent can be contaminated if exhaled gas is appropriately filtered. It is possible that absorbents may become in short supply which argues for not changing the absorbent unless it is necessary.
- If an anesthesia machine has been used long-term on COVID-19 infected patients, or there is evidence that the internal surfaces of the machine have become contaminated, it should be terminally cleaned before using it in the operating room on non-COVID infected patients. Specific procedures can be found in the manufacturer guidelines. Some guidelines recommend quarantining the anesthesia machine from 21-28 days if there is suspected internal viral contamination to provide enough time for the virus to die before use with the next patient. This approach is not only impractical, but may impede the ability to care for patients. While there are no data to understand what cleaning procedures will eliminate the risk of viral transmission, the following procedure could be considered.
 - Remove and discard all disposables - circuit, filters, CO2 absorbent, mask, sampling line and associated water trap.
 - Following manufacturer instructions, sterilize the internal breathing system and ventilator components.
 - Wipe external surfaces with appropriate anti-viral cleaning solution
 - Replace the disposables with new clean/sterile replacements
 - Place a viral filter on the inspiratory limb for two to four weeks. This filter could be left in place between patients to conserve supply.

NOTE: Information can also be found on the APSF website: <https://www.apsf.org/faq-on-anesthesia-machine-use-protection-and-decontamination-during-the-covid-19-pandemic/#cleaning>

EDUCATIONAL MATERIAL ON CLINICAL MANAGEMENT OF CRITICALLY ILL PATIENTS WITH COVID-19

CAESAR ICU

COVID Activated Emergency Scaling of Anesthesiology Responsibilities (CAESAR) ICU is an educational program from the ASA Committee on Critical Care and the Society of Critical Care Medicine. This program is intended to provide guidance for managing critically ill patients with COVID-19 and is available to any healthcare professional.

The program can be accessed at <https://www.asahq.org/in-the-spotlight/coronavirus-covid-19-information/caesar>