

Using the anesthesia workstation as a ventilator for critically ill patients- Technical considerations

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Introduction

This document is intended to be a brief review of published guidance on using anesthesia workstations as ventilators for the critically ill. Please use caution and consult the original sources, as guidance statements are being published and revised on a very frequent basis.

Use of the anesthesia workstation as a ventilator for critically ill patients is an off-label use of the device, is entirely the responsibility of the user, and should be carefully considered before implementation. Any recommendations herein should be subject to local peer review before implementation.

Key words: Anesthesia gas machine; Covid-19; Coronavirus; Ventilator; ICU; Mechanical ventilation; CRNA; Nurse Anesthetist; Anesthesiologist

Who should run the anesthesia workstation

- **Should anesthesia workstations be used as ventilators for the critically ill?**
 - All manufacturers caution that the use is off-label, and the responsibility lies with the user. All offer guidance because the current situation is unprecedented.¹⁻³ The US Food & Drug Administration has given authorization for emergency use.^{4,5} The ASA (American Society of Anesthesiologists) & APSF (Anesthesia Patient Safety Foundation) have authored a joint guidance for use in critically ill patients.⁶
- **Anesthesia providers should setup, check, and manage the anesthesia workstation.**
 - GE- "There is a risk of serious injury or death if the devices are not used by properly trained clinicians, continuously monitored, and used in accordance with the instructions for use... The devices are intended to be used by clinicians who are trained in the administration of general anesthesia. There are unique characteristics that differentiate anesthesia devices from standard ICU ventilators... All users should be familiar with the anesthesia system user interface, controls, functions, configurations, alarms, and theory of operation before using these devices."¹ "Because anesthesia devices are designed as attended devices, most anesthesia devices do not continue ventilation... in the event of a critical device malfunction."¹
 - Drager & Mindray offer similar guidance.^{2,3} ASA/APSF state "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."⁶
- **Anesthesia providers must be in constant attendance or immediately available to respond to alarms and make appropriate adjustments.**
 - GE "Anesthesia devices are designed and intended to be fully attended/monitored devices, which requires a clinician to be in proximity of the device at all times. This is different from

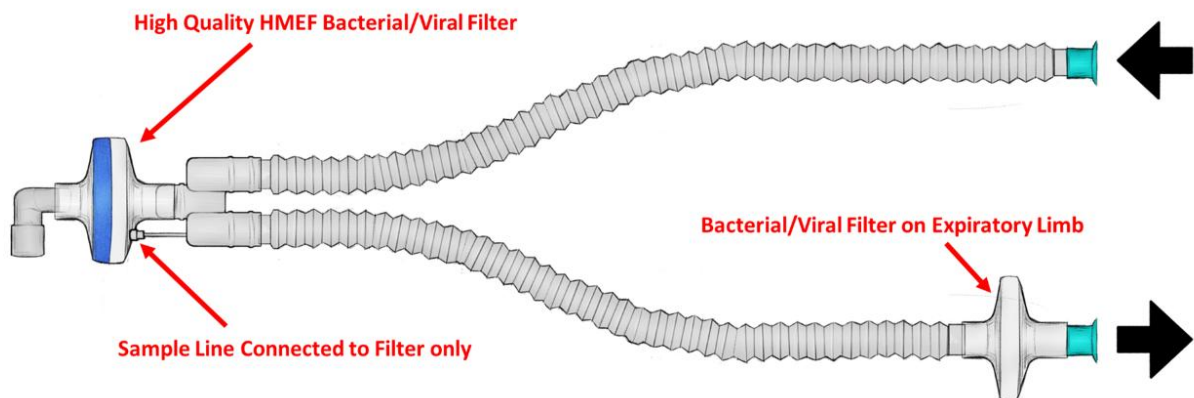
the potential use case in ICU ventilation. It is critical to ensure the proper use and continuous monitoring of the anesthesia device function and ventilation is maintained... Anesthesia systems are designed for use in an attended environment. Device audio alert levels (volume) may not be adequate for the ICU use environment. Ensure the device audio level is adequate for the ICU or provide alternative methods of continual status monitoring. The anesthesia machines do not have the ability to generate alerts via the hospital nurse call alarm systems."¹

- Dräger & Mindray offer similar guidance.^{2,3} "The user interface of Dräger anaesthesia devices cannot be protected against non-authorized users. Therefore, the operating organisation must ensure that non-authorized users cannot approach the device to avoid that settings are changed, or therapy is stopped (no alarm is generated when device is switched to standby)... The alarm and safety concept of Dräger anaesthesia is designed for a permanent presence of the user within a distance of up to four meters... remote supervision (e.g. via central station) is not sufficient."²
- ASA/APSF "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."⁶

Breathing circuit

- **Fresh gas flow (FGF)**- The lower fresh gas flows that anesthesia providers are accustomed to (1-2 L/min) are advantageous in short term ventilation, by conserving tracheal heat and humidity, and giving economy of volatile agents. For chronic ventilation, lower FGF may cause excessive water vapor in the circuit, and condensation. This may interfere with flow sensors, accuracy of tidal volume delivery, and trigger additional breaths (as exhalations bubble through collected water in the expiratory limb). Higher FGF uses a large amount of oxygen, and dries the tracheal mucosa. For these reasons, manufacturers have suggested fresh gas flows of:
 - GE- 50% or more of patient's minute ventilation ($VE = VT \times RR$).¹
 - Dräger- 150% of VE .²
 - Mindray- 100% of VE .³
 - If using lower FGF, **increase FGF > VE for 15 min every four hours** to help dry the internal components of the circuit.⁶
- **N₂O & Vaporizers**- The use of nitrous oxide or vaporized anesthetics is not recommended.^{1-3,6} It is advised that vaporizers be removed to prevent triggering malignant hyperthermia, among other reasons. "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. Certainly, this is not advised without proper waste anesthetic gas scavenging which will typically only be available in the OR. The potentially detrimental effects of long term sedation with inhaled anesthetics have not been studied. Provision of inhaled anesthesia would require constant presence of an anesthesia provider at the bedside to monitor the physiologic effects."⁶
- **Scavenging**- In addition to the above, it is recommended that " Scavenging is not required or necessary if appropriate viral filters are placed on the circuits.... Suction outlets are available in the ICU but cannot be attached to the WAGD [Waste Anesthesia Gas Disposal] connection on the machine due to connector incompatibility."⁶

- **Suctioning** Switch to Manual/Spontaneous ("bag" mode) during tracheal suctioning.¹
- **Conserving humidity, oxygen, carbon dioxide absorbent-**
 - Humidity is conserved by use of lower FGF, and by using heat moisture exchange filter (HMEF) at the Y junction of the breathing circuit.⁶ Active humidification is not recommended. Users should be vigilant for accumulation of water in circuit hoses, monitor water traps, HMEFs, and condensers if present.
 - Oxygen may be conserved by low FGF, by using a workstation with an electrically-powered bellows (Drager) rather than a gas-powered bellows (GE), or by switching the drive gas from oxygen to compressed air in a GE machine (typically done by a service technician, not an anesthesia provider or anesthesia tech).⁶
 - CO₂ absorbent is utilized faster at low FGF, and much less at high FGF. If there is a shortage of CO₂ absorbent, "... (and the supply of oxygen is not a concern): Increase total fresh gas flow to meet or exceed minute ventilation. CO₂ absorbents will be utilized very little, if at all, since the goal is to reduce rebreathing. If inspired CO₂ is present on the capnogram, increasing total fresh gas flow until the inspired CO₂ is zero will eliminate rebreathing. The lack of humidity in the fresh gas may become a problem."⁶
- **Infection control** - While a complete discussion is beyond the scope of this article, a few points may be made.⁷
 - Protect the machine and the patient with high efficiency HMEF at the Y piece of the breathing circuit, and at the machine end of the expiratory limb. Airway gas sampling should be done from a port on the machine side of the HMEF at the Y.



- "If the sampled gases end up in the scavenging system, no further filtering is needed."⁸
- "If you are using a gas analyzer that is not integrated into the anesthesia machine it is easy to trace the exhaust gas and it should go to an active (not passive) scavenging system, not the room. For integrated gas analyzers, the connections are usually hidden."⁸
- "If sampled gases are returned to the breathing circuit they need to be filtered [e.g. Aisys CS2 software version 11, Apollo, Perseus]. Water traps do have built in filters and the viral filtration efficiency (VFE) determines the effectiveness. The GE DFend Pro water traps include a 0.2 micron filter with a VFE of 99.999%. Draeger uses a 0.2 micron filter in the water trap but the VFE has yet to be determined. If an airway filter option is not available, and the water trap filter cannot be confirmed, a 0.2 micron drug injection filter similar to that used in epidural kits can be placed at the water trap."⁸
- "If the sampled gas is routed to the scavenging system, additional filtration may not be necessary as there are standards for managing biohazards in the central suction system or

waste anesthetic gas system (WAGS). Check with the local facilities manager to confirm the risk of biohazard in the suction system. Unfiltered Sampled gas should not be exhausted directly into the OR [or ICU] environment or a passive scavenging system."⁸

- **Backup** An anesthesia workstation must never be used without a means of backup ventilation (Bag-valve-mask device [Ambu]), and an emergency cylinder supply of oxygen.

Monitoring

- **Continuous monitoring** of airway gas (particularly inspired oxygen & capnometry), airway pressures, and volumes (tidal and minute) are absolutely essential because of the unique aspects of the anesthesia breathing circuit (rebreathing, CO₂ absorbent, scavenging, & the divergence of dialed and inspired oxygen at low FGF).^{1,2,6}
 - **Alarms** must be set to appropriate limits, with audible alarm volume at 100%.
 - "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."⁶
- **Periodic checks**- Manufacturers highly recommend that the device be rebooted/restarted at least every 24 hours.¹⁻³ Failing to do so results in degradation of pressure flow and volume monitoring, and breath triggering (GE), and flow measurement (but not respiratory gas monitoring -Drager). Anesthesia workstations cannot be checked while in operation, so the patient must be ventilated via alternate techniques during the 5-10 minutes required for checkout or restart.

Ventilation for ARDS related to COVID-19

- Most patients in normal times do not have a severe degree of lung pathology. Discussion of ventilation for ARDS is well beyond the scope of this document; please see the excellent discussion at <https://www.uptodate.com/contents/ventilator-management-strategies-for-adults-with-acute-respiratory-distress-syndrome>.⁹ Key points of that discussion are summarized below.
- **Anesthesia workstations are not recommended for:** long-term ventilation of pediatric or neonatal patients,¹ non-invasive ventilation,¹ administering nebulized drugs,² or for ventilating multiple patients simultaneously.¹⁰
- **OR or ICU?** " If the device is moved ...outside of its normal location in the OR, the device must be re-installed/configured by professionals trained in the proper setup of facility connections such as scavenging and gas inputs."¹
 - **"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. Suction outlets are available in the ICU but cannot be attached to the WAGD [waste gas] connection on the machine due to connector incompatibility."⁶
 - **"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."⁶

- **"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."⁶
- **Settings & Targets**
 - **Mode** - either pressure or volume control is acceptable.⁹
 - **Tidal volume (VT):** For lung protective ventilation, suggested starting VT is **6 mL/kg ideal body weight** (range 4-8).⁹ Ideal body weight is also known as predicted body weight (PBW). Some electronic medical records calculate and display ideal BW. If you need to calculate it, see *Clinical Mathematics for Anesthetists*.¹¹
 - For the **average US female** (height 5 ft 4 in), starting VT is 330 mL (range 220-440). Over heights from 60-72 in, starting VT is 270-440 mL/kg.
 - For the **average US male** (height 5 ft 9 in), starting VT is 425 mL (range 280-560). Over heights from 60-72 in, starting VT is 300-460 mL/kg.
 - **F_IO₂ & PEEP-** "...set PEEP at 5 cm H₂O and F_IO₂ at 1 at the onset of initiation of mechanical ventilation; the F_IO₂ is rapidly weaned over the next hour to target a peripheral saturation (SpO₂) of 88 to 95 percent (typically low to mid 90s)."⁹ Keep in mind that F_IO₂ of 1.0 promotes atelectasis through absorption of all the oxygen in poorly-ventilated alveoli. Keeping some nitrogen in the breathing mixture (F_IO₂ 0.8 or less) prevents atelectasis from this cause.¹²
 - **Respiratory rate (RR)-** "... initial VT is set at 6 mL/kg Predicted Body Weight and the initial respiratory rate is set to meet the patient's minute ventilation requirements, provided it is ≤35 breaths per minute (most often between **14 and 22 breaths/minute**)."⁹
 - **SpO₂-** the target is peripheral saturation (SpO₂) of **88 to 95 percent** (typically low to mid 90s)."⁹
 - **pETCO₂ & Permissive hypercapnia** – "Hypercapnic respiratory acidosis ... is an expected and generally well tolerated consequence of LTVV [Low Tidal Volume Ventilation]. LTVV may require permissive hypercapnic ventilation, a strategy that accepts alveolar hypoventilation in order to maintain a low alveolar pressure and minimize the complications of alveolar overdistension (eg, ventilator-associated lung injury). The degree of hypercapnia can be minimized by using the highest respiratory rate that does not induce auto-PEEP."⁹
 - **Plateau pressure (Pplat)-** Pplat can be measured directly if volume control with inspiratory pause is utilized. "Over the next one to four hours, the patient's clinical response, gas exchange, and Pplat can be used to adjust the VT and respiratory rate, if necessary. Clinicians are encouraged to make bedside adjustments to VT to ensure lung protective ventilation is being appropriately administered and to assess response in real-time before obtaining arterial blood gases. Typically adjustments are made simultaneously to meet clinical and gas exchange, as well as Pplat parameters... The goal Pplat is ≤**30 cm H₂O**..."⁹
 - "When the Pplat is >30 cm H₂O and the VT is set at 6 mL/kg PBW or higher, the VT should be decreased in 1 mL/kg PBW increments to a minimum of 4 mL/kg PBW to reach the target plateau. Importantly, any decrease in VT may need to

be accompanied by an increase in respiratory rate to maintain an acceptable minute ventilation."⁹

- **Driving pressure**- " Lung-protective ventilation strategies are associated with limited driving pressure ... we track driving pressure in patients in severe or refractory ARDS to identify those with recruitable lung who may benefit from high levels of PEEP. Although a cutoff value has not been agreed upon, we and others use a target ... **< 20 mmHg**."⁹
Driving pressure may be calculated as:
 - ventilator-measured Pplat minus applied PEEP, or
 - VT /respiratory system compliance, or
 - (modified as) Peak inspiratory pressure minus PEEP.
- **Alveolar recruitment maneuvers (ARM)**- Open lung strategies include ARM, which "... recruit additional atelectatic alveolar units and the applied PEEP maintains alveolar recruitment and minimizes cyclic atelectasis; this combination, in theory, should reduce the risk of inducing further lung injury by the mechanical ventilator itself."⁹ There is no consensus on one way to perform an ARM. The Aisys has two strategies built in (under the Procedures button on the main screen)- one which holds a selectable pressure (try 30 cm H₂O) for a selectable time (try 15-20 seconds). Monitor blood pressure, because increasing mean intrathoracic pressure can decrease venous return.
- **pH** - "There is no consensus regarding an acceptable lower or upper limit for pH ... most experts agree that ... a pH below 7.25 and above 7.5 should be addressed while maintaining LTVV (ie, a VT between 4 and 8 mL/kg PBW and a pPlat ≤30 cm H₂O)."⁹
- **Alternative means of ventilation** - If resources are ultimately strained, last ditch alternatives to consider might include: Simple devices operating in volume control (Bear) or pressure control mode (Bird), or manual ventilation by Bag-valve-mask device.¹³⁻¹⁵

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Disclosures, Disclaimer, and Acknowledgements

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Appendix: Links

- <https://www.apsf.org/novel-coronavirus-covid-19-resource-center/>

- <https://www.apsf.org/news-updates/perioperative-considerations-for-the-2019-novel-coronavirus-covid-19/>
- <https://www.apsf.org/faq-on-anesthesia-machine-use-protection-and-decontamination-during-the-covid-19-pandemic/>
- <https://www.gehealthcare.com/corporate/covid-19>
- https://www.draeger.com/en-us_us/Home/novel-coronavirus-outbreak (scroll down for information on reprocessing of Perseus, Apollo, Fabius; and guide to cleaning solutions)