Use of Anesthesia Machines in a Critical Care Setting During the Coronavirus Disease 2019 Pandemic

Kent M. K. Haina Jr, MSN, CRNA

The coronavirus disease 2019 (COVID-19) pandemic created an unprecedented need for mechanical ventilation in critically ill patients. To meet this increased demand, some facilities were forced to use anesthesia gas machines (AGMs) as intensive care unit (ICU) ventilators. While an off-label use, AGM manufacturers, the Anesthesia Patient Safety Foundation, and the American Society of Anesthesiologists have guidelines for AGM use in the ICU, however, there is scant literature describing their use. This article describes our experiences at New York University Langone Medical Center using AGMs in the ICU for ventilating critically ill COVID-19 patients. (A&A Practice. 2020;14:e01243.)

GLOSSARY

AGM = anesthesia gas machine; **APSF** = Anesthesia Patient Safety Foundation; **ASA** = American Society of Anesthesiologists; **COVID-19** = coronavirus disease 2019; **CRNA** = Certified Registered Nurse Anesthetist; **Etco₂** = end-tidal carbon dioxide; **ETT** = endotracheal tube; **FDA** = US Food and Drug Administration; **FGF** = fresh gas flow; **Fico₂** = inspired fraction of CO₂; **HME** = heat and moisture exchanger; **ICU** = intensive care unit; **PEEP** = positive end-expiratory pressure; **PPE** = personal protective equipment

In January 2020, a coronavirus was identified in Wuhan, China.¹ Coronavirus disease 2019 (COVID-19), the disease caused by this virus, is notable for its progression to severe respiratory failure, necessitating intensive care including intubation and mechanical ventilation.² The infection quickly spread, creating a global pandemic. Many hospitals were overwhelmed with patients, particularly those requiring supportive ventilatory care. With the overwhelming number of patients in respiratory failure, some hospitals ran out of ventilators. While anesthesia gas machines (AGMs) are not designed for long-term ventilation and do not have sophisticated, efficient ventilation modes found on traditional ventilators, they are capable of providing mechanical ventilation. Many hospitals had AGMs available due to substantial decreases in surgical cases. In March of 2020, the US Food and Drug Administration (FDA) released a policy allowing for the use of AGMs to make up for the shortage of ventilators.³ The American Society of Anesthesiologists (ASA) and the Anesthesia Patient Safety Foundation (APSF) have jointly released guidelines and references for using AGMs as intensive care unit (ICU) ventilators (considered an off-label use); however, there is scant literature describing their use in practice.⁴ This article describes our experiences in a 34-bed ICU with up to 34 AGMs, their management, and common issues we encountered.

DESCRIPTION

At New York University Langone Medical Center, a 34-bed inpatient unit was converted into an ICU devoted to caring for patients with COVID-19. Due to the shortage of available ventilators in the hospital, each room utilized an AGM (Apollo Anesthesia Machine; Draeger, Lubeck, Germany) for mechanical ventilation. Throughout the patient's stay, if a traditional ventilator became available, the anesthesia machine was replaced with the ventilator. On each AGM, the nitrous oxide cylinder and all vaporizers were removed, and the scavenging system was disconnected. Following APSF guidelines, an elbow connector, connected to a water trap by an end-tidal carbon dioxide (Etco₂) sample line, was attached to the Y-piece of the breathing circuit, followed by a heat and moisture exchanger (HME) (Figure 1). Initially, we attached a second HME and an electrostatic filter to the end of the expiratory limb of the circuit to minimize risk of contamination to the AGM (Figure 2A). After consulting Draeger guidelines, the second HME was removed from the expiratory limb of the circuit to preserve supplies and decrease airway resistance and dead space (Figure 2B).⁵

Due to the differences between critical care ventilators and AGMs, the FDA, ASA, and APSF recommend that an anesthesia provider be available at all times to manage the AGM.^{3,4} Accordingly, 2–4 Certified Registered Nurse Anesthetists (CRNAs) were scheduled, 24 hours a day, 7 days a week, on the unit to assist with machine operation, troubleshooting, and patient ventilatory care. CRNAs participated in AGM rounds at least every 12 hours and on an as-needed basis. Rounding duties included confirming ventilator settings and fresh gas flow (FGF), assessing the inspired fraction of CO₂ (Fico₂) and CO₂ absorbent, checking for condensation and standing fluid in the breathing circuit, Etco₂ sample line, and water trap, and assessing HMEs for condensation and occlusion and replacing them

From the Department of Anesthesiology, Perioperative Care & Pain Medicine, New York University Langone Medical Center, New York, NY.

Accepted for publication May 11, 2020.

Funding: None.

The authors declare no conflicts of interest.

Address correspondence to Kent M. K. Haina Jr, MSN, CRNA, Department of Anesthesiology, Tisch Hospital, 550 First Ave, New York, NY 10016. Address e-mail to kent.haina@nyulangone.org.

Copyright © 2020 International Anesthesia Research Society
DOI: 10.1213/XAA.0000000000001243

Figure 1. Picture of the end of the breathing circuit with Y-piece, heat and moisture exchanger, elbow connector, end-tidal carbon dioxide sample line, water trap, and endotracheal tube labeled.

Figure 2. Expiratory limb filters. A, Picture of the end of the expiratory limb of the breathing circuit with a heat and moisture exchanger and electrostatic filter attached. B, Picture of the end of the expiratory limb of the breathing circuit with an electrostatic filter only attached.

if necessary. CRNAs also collaborated with the intensivists on changing ventilator settings to improve patient oxygenation and ventilation.

For HME changes, the patient was placed on 100% oxygen before the change to increase the patient's oxygen reserves. FGF was then turned off, a piece of gauze was

placed around the endotracheal tube (ETT), and a surgical clamp was used to occlude the ETT (Figure 3) at end inspiration to maintain alveolar recruitment, to prevent inspiratory effort and negative pressure pulmonary edema, and to minimize risk of viral spread.^{6,7} The machine was placed on manual, spontaneous mode, and the filter was quickly changed. The circuit was then reconnected, the ETT unclamped, and the patient placed back on previous ventilator settings.

DISCUSSION

Daily Self-Test

Draeger recommends running a full system test every 24 hours for their AGMs, or, at a minimum, every 72 hours to decrease the probability of the device malfunctioning.⁵ During such a test, ventilation with the AGM is impossible for up to 8 minutes, requiring an alternative form of ventilation, typically a portable ventilator or manual resuscitator. Given the risk of exposure to health care providers by removing the circuit from the ETT, as well as the potential harm of alveolar derecruitment, the daily test was performed only if a patient was extubated or if they no longer needed the AGM before its use on another patient. This time span was typically >72 hours.

Heat and Moisture Exchanger

HMEs were initially replaced every 12 hours to prevent obstruction. We quickly transitioned to changing the HME as needed, doing so only if the HME was saturated with condensation or clogged with secretions. This was done to avoid exhausting supplies. The date and time of the HME change was documented on the patient's door to identify patients using HMEs at an increased rate and to indicate that the patient needed more frequent rounding. HME changes were typically well tolerated by appropriately sedated patients. More awake patients often required a bolus of sedative medications to safely accomplish the exchange. Patients who did not tolerate HME changes desaturated, coughed, and experienced patient-AGM dyssynchrony, requiring recruitment maneuvers, neuromuscular blockers, more sedation, increased positive end-expiratory pressure (PEEP), or increased oxygen.

Fresh Gas Flow

To simplify workflow and make oxygen changes quick and efficient, all patients were placed on the same total FGF rather than patient-specific flows. While Draeger guidelines recommend using FGFs that are 150% of minute ventilation and ASA/APSF guidelines recommend FGF greater than or equal to minute ventilation, total FGF for each patient was started at 5L/min (typically less than the patient's minute ventilation) to preserve humidity and hospital oxygen supply.^{4,5} Many patients with FGF less than minute ventilation developed excessive humidity and condensation in the breathing circuit, increasing resistance to flow, and creating sensor malfunction. Excess condensation required emptying of the expiratory limb of the breathing circuit, suctioning of the ETT, and frequent HME changes. Condensation also contributed to patient-AGM dyssynchrony, because bubbling fluid in the breathing circuit can be sensed erroneously

Figure 3. Endotracheal tube clamped with surgical clamp and gauze for heat and moisture exchanger change.

as a patient inspiratory effort, triggering an AGM given breath.⁴ In addition, 5L/min of FGF necessitated relatively frequent CO₂ absorbent canister changes. FGF changes for patient-specific problems such as high FICO₂ were made in consultation with the intensivist.

Eventually the total FGF was increased to 10L/min for all patients to decrease condensation in the breathing circuit. It was also clear at this time that our hospital had

adequate O₂ supply to meet the patients' needs. Increased FGF decreased condensation in the breathing circuit, the associated HME changes, and the frequent CO₂ absorbent canister changes. This increased FGF also did not violate current guidelines.

Water Trap and Sample Line

Due to excessive humidity in some breathing circuits, water traps and EtCO₂ sample lines were monitored closely. To preserve supplies, they were emptied if possible and only replaced if the monitor was unable to register an EtCO₂ reading.

Other Issues

There were other problems surrounding the unique use of AGMs as ICU ventilators for the COVID-19 population. Alarm volumes and limits required close monitoring, especially due to the isolation of each patient requiring closed doors to maintain negative pressure rooms. It is also important to note that the work of CRNAs in the ICU was particularly labor and time intensive with proper donning and doffing of personal protective equipment (PPE). To ensure sufficient PPE, PPE was often cleaned and reused. There was 1 case of sudden, total AGM failure, necessitating bag mask ventilation until the machine was restarted and the self-test was performed. While AGMs are useful for mechanical ventilation, they do not have the same features as traditional ventilators, nor are they designed for long-term ventilation. Patients who were eventually transitioned to traditional ventilators were ventilated more efficiently on the traditional ventilator than on the AGM, with better tidal volumes, lower peak pressures, and lower required PEEP. No serious adverse events were noted from use of the AGMs.

CONCLUSIONS

Although not without challenges, AGMs can be safely used for the care of critically ill patients requiring mechanical ventilation. It is important that an anesthesia provider be available at all times to manage the AGM, with special attention given to current guidelines and the following:

- Confirm ventilator settings and alarm volumes and limits.
- Perform the self-test as needed.
- Maintain total FGF 10 L/min to avoid condensation issues and frequent HME changes and to simplify workflow.

- Monitor the EtCO₂ sample line, water trap, CO₂ absorbent, and HME for replacement.
- Check the expiratory limb of the breathing circuit for condensation and pooled liquid.

If there is a need for AGMs outside of a typical operating room for long-term ventilation, while they are not as sophisticated, efficient, or easy to use as traditional ventilators, they may be a suitable backup. ■■

DISCLOSURES

Name: Kent M. K. Haina Jr, MSN, CRNA.

Contribution: This author helped write the submitted manuscript.

This manuscript was handled by: BobbieJean Sweitzer, MD, FACP.

REFERENCES

1. Peng PWH, Ho PL, Hota SS. Outbreak of a new coronavirus: what anaesthetists should know. *Br J Anaesth*. 2020;124:497–501.
2. Sommer P, Lukovic E, Fagley E, et al. Initial clinical impressions of the critical care of COVID-19 patients in Seattle, New York City, and Chicago [ePub ahead of print]. *Anesth Analg*. 2020.
3. U.S. Food and Drug Administration. Ventilator Supply Mitigation Strategies. 2020. Available at: <https://www.fda.gov/medical-devices/letters-health-care-providers/ventilator-supply-mitigation-strategies-letter-health-care-providers>. Accessed April 5, 2020.
4. APSF/ASA Guidance On Purposing Anesthesia Machines As ICU Ventilators. American Society of Anesthesiologists. 2020. Available at: <https://www.asahq.org/in-the-spotlight/coronavirus-covid-19-information/purposing-anesthesia-machines-for-ventilators>. Accessed April 13, 2020.
5. Thams I, Heesch R, Rahlf-Luong M. COVID-19: Usage Of Draeger Anaesthesia Devices For Long-Term Ventilation. Draeger; 2020. Available at: <https://www.draeger.com/Library/Content/Draeger%20Customer%20Letter%20-%20COVID-19%20-%20Usage%20of%20Anesthesia%20devices%20for%20long%20term%20ventilation-2020-03-18.pdf>. Accessed April 5, 2020.
6. Feldman J, Loeb R, Philip J. FAQ on Anesthesia Machine Use, Protection, and Decontamination During the COVID-19 Pandemic - Anesthesia Patient Safety Foundation. Anesthesia Patient Safety Foundation. 2020. Available at: <https://www.apsf.org/faq-on-anesthesia-machine-use-protection-and-decontamination-during-the-covid-19-pandemic/#ventilator>. Accessed April 5, 2020.
7. Madden M, Andrews P, Lear G, Habashi N. Clamping the endotracheal tube using optimal clamping technique prior to disconnection maintains airway pressure reducing risk of derecruitment. *Resp Care*. 2016;61:OF42–OF42.