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

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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

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).

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. 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...
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 5 L/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 dysynchrony, because bubbling fluid in the breathing circuit can be sensed erroneously as a patient inspiratory effort, triggering an AGM given breath.4 In addition, 5 L/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 10 L/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
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Contribution: This author helped write the submitted manuscript.
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