

Anesthesia Machine Failure: A Case Study

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This article examines successful management of an anesthesia machine failure with the Draeger (or Dräger) Apollo (Draeger Inc) anesthesia workstation. Approximately 45 minutes into the case, while the patient was under general anesthesia and mechanical ventilation, the anesthesia machine failed to achieve positive pressurization following a high-pressure alarm. Despite multiple maneuvers, the issue did not resolve until the

machine was manually powered off and on at the main power switch. This case report emphasizes the importance of always having a backup means of patient ventilation and anesthesia administration.

Keywords: Anesthesia machine, Draeger Apollo, machine failure, mechanical ventilation.

Following development of compressed oxygen and nitrous oxide stored in gas cylinders, Dr James Gwathmey, in 1913, developed a simple flow meter-type apparatus whereby compressed gases could be administered to patients.¹ In 1917, Dr H. E. G. Boyle made modifications to the device, creating the first anesthesia gas delivery equipment or anesthesia machine.² Since this time, improvements in anesthesia machine design have been made for increased patient safety (interlocking system, low-pressure alarms), specialized modes of mechanical ventilation, and the special requirements for desflurane vaporization. Despite the many improvements in design of anesthesia machines made over the past century, anesthesia machine failure, while rare, is a potential cause of anesthesia mishap.³ This case study will discuss the successful management of failure of an anesthesia machine (Draeger [or Dräger] Apollo, Draeger Inc).

Case Summary

A 64-year-old patient weighing 60 kg was scheduled as the second case of the day for removal of a lumbar fixation device and re-instrumentation of lumbar levels L4, 5, and 6. The patient was classified an ASA class 3 because of a 70-pack year history of smoking, hypertension, and chronic obstructive pulmonary disease. The patient's medications were taken on the morning of surgery. The patient denied any drug allergies, and the anesthesia and surgical history was unremarkable.

The anesthesia machine functioned without incident on the first case of the day, and a full electronic check of the anesthesia machine was completed at 5 AM. For this second case of the day, the new breathing circuit passed the manual high-occlusion leak test. Further manual testing demonstrated appropriate ventilator and circuit functionality when tested with a second reservoir bag. The open scavenger system showed appropriate suctioning and scavenging abilities.

Following premedication with midazolam, 2 mg IV, in the preoperative holding area, the patient was transported to the operating room. During preoxygenation, the electrocardiogram, noninvasive blood pressure cuff, and pulse oximetry monitors were applied. An intravenous (IV) infusion of vancomycin was initiated. Normal, expected bag movement during patient inspiration (bag collapse) and expiration (bag filling) was observed. Induction was accomplished intravenously with the patient on the transport cart with midazolam, 3 mg; lidocaine, 100 mg; propofol, 200 mg; and ketamine, 50 mg. After the ability to provide adequate mask ventilation was confirmed, succinylcholine, 140 mg IV, was administered, followed by successful endotracheal intubation. On auscultation of the patient's lungs, breath sounds were equal bilaterally with bibasilar wheezing. Albuterol, 1-mg nebulization, was administered via the endotracheal (ET) tube along with sevoflurane to an end-tidal concentration of 1%, and wheezing disappeared. Because somatosensory and motor evoked potentials were to be monitored intraoperatively, a reduced dose of inhalational agent (0.5 minimum alveolar concentration preferred) was administered without additional neuromuscular blocking agent. The patient was placed on volume control mechanical ventilation at a rate of 10/min and a tidal volume of 500 mL, producing peak inspiratory pressures of 15 cm H₂O.

The patient was positioned and secured in the right, flexed, lateral decubitus position. After positioning, lung fields were auscultated and found to be equal and clear bilaterally. Anesthesia was maintained with 1% sevoflurane (end-tidal) administered with 50% air and oxygen, and IV infusions of lidocaine, 1.5 mg/min; ketamine, 2 µg/kg/min; magnesium sulfate, 1 g (infused over 30 minutes); and fentanyl, 250 µg (administered incrementally over 20 minutes).

Approximately 45 minutes into the case, and just before the incision, the continuous high-pressure

alarm—a possible indicator of ventilator relief valve failure⁴—alerted, and mechanical ventilation ceased. At this time, volume-controlled mechanical ventilation was switched to manual ventilation mode, and 100% oxygen fresh gas flow was initiated. However, the circle system did not pressurize, rendering positive pressure ventilation impossible. Additional maneuvers failed to establish positive pressure in the breathing circuit, including fully closing the adjustable pressure-limiting valve and then filling the breathing circuit bag via the oxygen flush valve, increasing gas flow to 10 L/min, checking for disconnections, and adding air to the ET tube cuff. However, a large swishing sound was heard coming from inside the machine whenever a manual breath was attempted, indicating a leak to room air or the scavenger.

Manual ventilation was immediately initiated with the auxiliary bag-valve-mask device and 100% oxygen via the auxiliary oxygen supply on the anesthesia machine. The patient was moved from the operating table and placed supine on the transport cart. Ventilation was easily accomplished, and pulmonary auscultation found the lungs to be clear and equal bilaterally. The patient's vital signs remained normal, and the pulse oximetry oxygen saturation was 100% throughout. General anesthesia was maintained with propofol boluses.

An anesthesiologist and anesthesia technician came to the operating room and also determined that the anesthesia machine was unable to achieve positive pressure in the breathing circuit. The breathing circuit, carbon dioxide (CO₂) monitor sampling line, and CO₂ absorbent were changed out, followed each time by a manual check for positive pressure. Evaluation of the scavenger system found appropriate functioning with the bobbin floating inside prescribed parameters.⁵

The anesthesia machine was then manually turned off at the main power switch located on the front of the machine (Figure) as instructed by the manufacturer's device operating instructions,⁵ and all pipeline gas hoses were disconnected and then reconnected. After the anesthesia machine was powered back on, a full electronic anesthesia machine check was conducted and passed. Positive pressure was also tested electronically and manually (with the manual high-occlusion leak test).

The patient was manually ventilated until return of spontaneous respirations, at which time the patient was allowed to emerge from anesthesia. The anesthesia machine was removed for servicing by the biomedical engineer, and the case was rescheduled 1.5 weeks later.

Discussion

A literature search found one case study from 2011 on failure to ventilate with the Draeger Apollo anesthesia workstation,⁶ with conditions similar to our case. In this report, failure to ventilate with the anesthesia machine occurred twice on the same day in 2 separate cases and

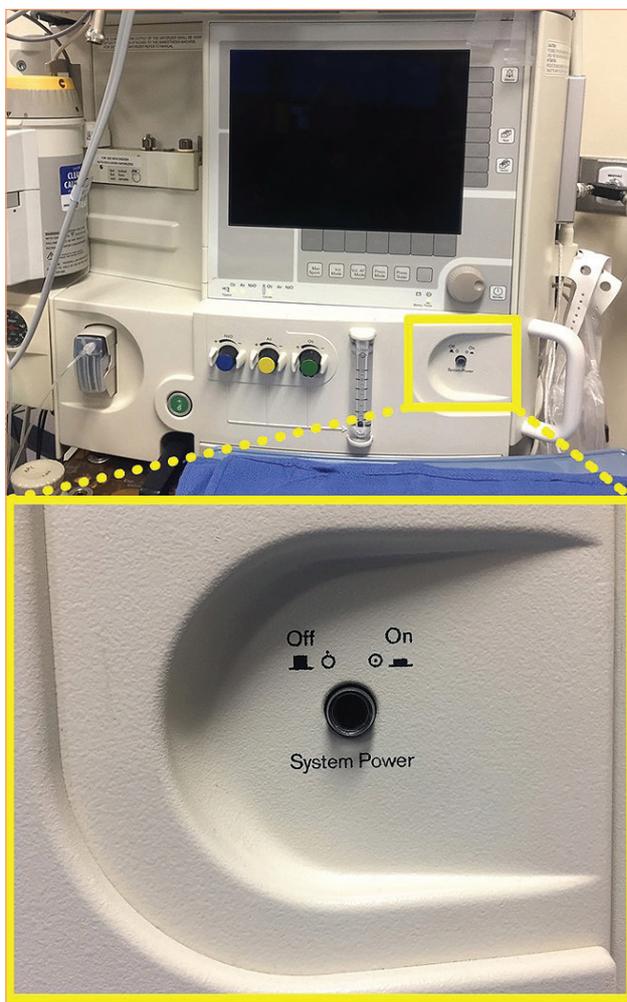


Figure. Draeger Apollo Anesthesia Machine (top) and Main Power Switch (bottom)

again later in a third case. The first incident occurred at the end of surgery when the patient's controlled ventilation was changed from mechanical to manual. After finding "no faults" by clinical engineers who checked the machine, the second case proceeded. Failure to ventilate occurred during induction when manual ventilation was initiated before insertion of the laryngeal mask airway device. The machine was removed from service, and a broken O-ring in the expiratory limb flow sensor was found and replaced. After the machine was returned to service, and at a later (unknown) date, it malfunctioned again during the second case of the day, despite functioning appropriately during the first surgical case. The machine functioned in both manual and controlled ventilation in the first case but suddenly failed to achieve positive pressure during induction in the second case, despite passing electronic and manual machine and circuit testing.

The machine was removed from service and "was put through rigorous investigations," which found that "downward pressure on the bag-arm-to-valve-body could

potentially cause a leak,” and the total adjustable pressure-limiting valve assembly was replaced.⁶ The machine’s error log report was sent to Draeger; however, the company did not find any errors that would explain the issue. Additionally, the authors hypothesized that the manual-auto valve may have remained open when mechanical ventilation was switched to manual ventilation mode.

In our case, the failure to ventilate problem occurred after a continuous high-pressure alert during volume-controlled ventilation. During the alert, the ventilator would cycle, but the patient was not ventilated as evidenced by absence of CO₂ on capnography and activated airway alarms. When mechanical ventilation was switched to manual ventilation, it still was not possible to ventilate the patient because the system did not pressurize. Not until the machine was manually powered off and back on at the main power switch, reminiscent of computer rebooting for personal computer failures, and underwent a full electronic and manual machine check did the machine pressurize. Because the surgical site, drapes, and equipment were contaminated when the patient was returned to the transport cart (immediately accessible outside the operating room) and by the entrance of an anesthesiologist and anesthesia technician, the case was canceled. The patient was allowed to emerge from anesthesia, and the anesthesia machine was removed from service. The error log was sent to Draeger; however, the company did not find any machine errors.

Interestingly, during periodic maintenance of our Apollo anesthesia machines by our biomedical engineer, a failure to pressurize issue developed following testing and activation of the continuous high-pressure alarm system. As occurred with this case, the issue did not resolve until the machine was manually powered off and on at the main power switch. This was reported to Draeger as well, but they were unable to find an error on the log.

As anesthesia machines become more computerized and dependent on electricity for functioning and monitoring of vital machine and patient systems, the risks for machine failure will increase. In fact, Draeger Apollo operating instructions state that if the machine fails to respond to an action or experiences a total failure during anesthesia delivery, such as changing from volume-

controlled ventilation to manual ventilation, the machine should be powered off and on (skipping the checkout procedure), while oxygen and ventilation are provided to the patient by an alternate route.⁵

This case emphasizes the importance of understanding the capabilities and limitations of the Draeger Apollo machine as well as of any anesthesia workstations being used to administer anesthesia. Additionally, this case demonstrates the importance of being able to provide immediate backup ventilation⁷ in case of anesthesia machine failure and keeping patient stretchers immediately available in case of emergency.

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DISCLOSURES

The authors have declared no financial relationships with any commercial entity related to the content of this article. The authors did not discuss off-label use within the article.