Failure to Ventilate with the Dräger Apollo® Anesthesia Workstation

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WE would like to report problems that occurred in our institution during our use of the Dräger Apollo® Anesthesia Workstation (Draeger Medical Inc., Telford, PA). The incidents seem to have occurred as a result of at least two separate faults.

CASE REPORTS

Case 1

This was the first patient on the schedule. The anesthesia machine passed the daily checks through the electronic system, and the circle breathing circuit had also been manually checked using the thumb-occlusion test by G.H. before the case. The patient was preoxygenated, during which time the bag was moving appropriately with inspiration and expiration. Anesthesia was induced with propofol and a *Laryngeal Mask Airway-Unique*™ (Laryngeal Mask Company Limited, San Diego, CA) was placed without difficulty. Manual ventilation *via* the machine through the *Laryngeal Mask Airway-Unique*™ was easily accomplished. The patient had good lung compliance, so little pressure was required to generate an adequate tidal volume. The ventilation mode was switched from manual to controlled ventilation because deep anesthesia was required for the procedure. At the end of the procedure, the patient was transferred smoothly to the gurney with the *Laryngeal Mask Airway-Unique*™ *in situ*. Controlled ventilation was switched to manual mode with the adjustable pressure-limiting (APL) valve fully open. The confirm wheel on the machine was pressed to activate the change in ventilation modes. In the Apollo® model, changing a ventilation mode is a two-step process involving one button to select the mode and a different button to confirm the selection before it is initiated. The patient at that point did not make any spontaneous respiratory effort, so the plan was to manually assist her until she had a regular respiratory pattern. Once the switch to manual mode was made, it was not possible to ventilate the patient; the bag remained empty despite fully closing the APL valve (which was free of obstructions[1–4]) using high fresh gas flows and activating the oxygen flush. There was a faint hissing sound at the time of squeezing the reservoir bag while there was still enough pressure in the circuit to try to attempt manual ventilation, but this was short-lived because the system quickly emptied, and no pressure could be generated. The sound of gas appeared to be coming from where the circuit attached to the inspiratory and expiratory limbs, but these connections were tested and intact. Was this a ventilation problem secondary to dislodgment of the *Laryngeal Mask Airway-Unique*™ during the transfer to the gurney? This seemed unlikely because the transfer had been very smooth without any strain on the circuit. As a precaution, the *Laryngeal Mask Airway-Unique*™ was removed and a Guedel airway placed before attempting ventilation using a backup device. It still was not possible to mask ventilate the patient *via* the machine bag because it was completely empty. Therefore, ventilation was changed from the machine to a bag valve mask, and ventilation of the patient was easily accomplished. A few minutes later, she commenced spontaneous respiration. The patient was stable throughout the incident.

Case 2

This was the second patient on the schedule. After case 1, the anesthesia technicians repeated the electronic leak test, and the machine passed. The technicians understood the problem that had been identified, but this was not reproducible during the second electronic test. A manual check of the machine for a leak was performed with a

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thumb-occlusion test, and no problems could be identified. Preoxygenation was accomplished with appropriate bag movement and normal end tidal capnography. Intravenous induction of anesthesia was performed as in case 1; an attempt at manual ventilation before insertion of the *Laryngeal Mask Airway-Unique*™ was not made. The *Laryngeal Mask Airway-Unique*™ was placed without any problems. Manual ventilation *via* the machine bag was again not possible, as in case 1, with the same hissing sound occurring. Ventilation was successfully obtained using a bag valve mask; anesthesia was maintained with propofol. Thus, there were no problems with the seating of the *Laryngeal Mask Airway-Unique*™. Anesthesia technicians returned to the room with clinical engineers, who checked the machine and still found no faults. They were able to generate positive pressure ventilation. During the bag valve mask and Guedal airway ventilation, clear fluid appeared from the patient's mouth (the patient had no history of gastroesophageal reflux disease), so he was immediately intubated after the administration of succinylcholine. There was no fluid in the inspiratory hose. The patient was stable throughout. Because the engineers could not find any fault with the machine, anesthesia was continued in a volume-controlled ventilation mode (manual ventilation was not tested on the patient *via* the machine before continuing in the controlled mode). At the end of the procedure, the controlled mode was switched to manual mode, and the patient immediately resumed spontaneous ventilation, so the reservoir bag did not need to be squeezed to generate positive pressure. The patient was extubated awake.

The machine was fully inspected by an engineer, who found the O-ring in the expiratory limb flow sensor was broken. An O-ring that is compromised can cause a leak, so the O-ring was replaced. A full inspection of the machine was performed. The machine was then put back into service and used without any problems on multiple patients. However, 2 weeks later problems occurred again.

Case 3

The same machine that was used in cases 1 and 2 passed the electronic test at the start of the day. There was no problem with the first patient on the schedule in either the spontaneous or controlled ventilation modes. Manual check of the circuit was performed before each patient use, and no problems were detected. The clinician did not specifically check on the state of moisture in the breathing manifold/piston diaphragm. The second patient on the schedule was preoxygenated while the bag inflated and deflated appropriately. After intravenous induction of anesthesia, it again was not possible to manually ventilate the patient *via* the machine bag, so a muscle relaxant was not given. Correct mask positioning was verified. Once again, the machine bag remained empty despite that the APL valve was closed and high fresh gas flows were used. A hissing noise appeared to come from the flow sensor area, as occurred in cases 1 and 2. Ventilation was changed to a bag valve mask, and anesthesia was maintained with propofol. The patient was stable throughout. Because of a delay in obtaining a replacement anesthesia machine, anesthesia was discontinued and the patient was allowed to wake. The anesthesia machine was taken out of service for the second time. The problem in case 3 appeared to G.H. to be the same as that in cases 1 and 2.

Discussion

A literature search could not identify that these failure-to-ventilate problems have been published previously. There are four published reports of failure to ventilate as a result of the gas sampling line trapped under the APL valve. All four published reports have been on Dräger anesthesia machines (Fabius GS Premium,[1] Apollo,[2] Optima,[3] and Fabius[4]). Dräger has modified the APL valve on newer machines to reduce the incidence of lines becoming trapped under the APL valve.[1] In the three events we report, the gas sampling line was not trapped under the APL valve.

Clinical engineering's tests of the machine after the first two events suggested that a defective O-ring in the flow sensor had caused the malfunction, and the O-ring was replaced. In addition, the O-ring in the bag arm connection was found to be broken, and it was replaced. However, if the O-ring in the flow sensor had been the main and only cause of the problem, we would not have been able to generate pressure for the ventilator to function, but in cases 1 and 2 the ventilator did work. The machine in question, which had been in service since December 2006, was put through rigorous investigations. During the investigation, it was found that downward pressure on the bag-arm-to-valve-body connection could potentially cause a leak. During the three cases reported here, there was never any downward pressure exerted on the bag arm. This should be noted as an incidental finding on the Dräger Apollo® machines because it could be replicated on other machines. The screws connecting the bag arm to the valve body must always be properly seated and tightened to avoid this type of leak.

All of the problems mentioned above occurred during use in the manual mode. Could the APL valve have gotten stuck in the open position internally, despite the control knob having been turned to the closed position externally? The Man-Auto valve (APL bypass valve) was inspected and replaced as a precaution. At a later time, after the second bag failure, the entire valve body (fresh gas decoupling valve, scavenging valve, Man-Auto valve, positive end expiratory pressure valve, expiratory valve, inspiratory valve, heater block) was replaced.

Could a fault with the electronically controlled Man-Auto valve (see fig. 1, shaded area) have caused it to stick in the bypass direction, thereby diverting inspiratory gas flow directly to the scavenging system? Although we believe that this is the most likely explanation, it could not be confirmed. The machine's error log was sent to Dräger

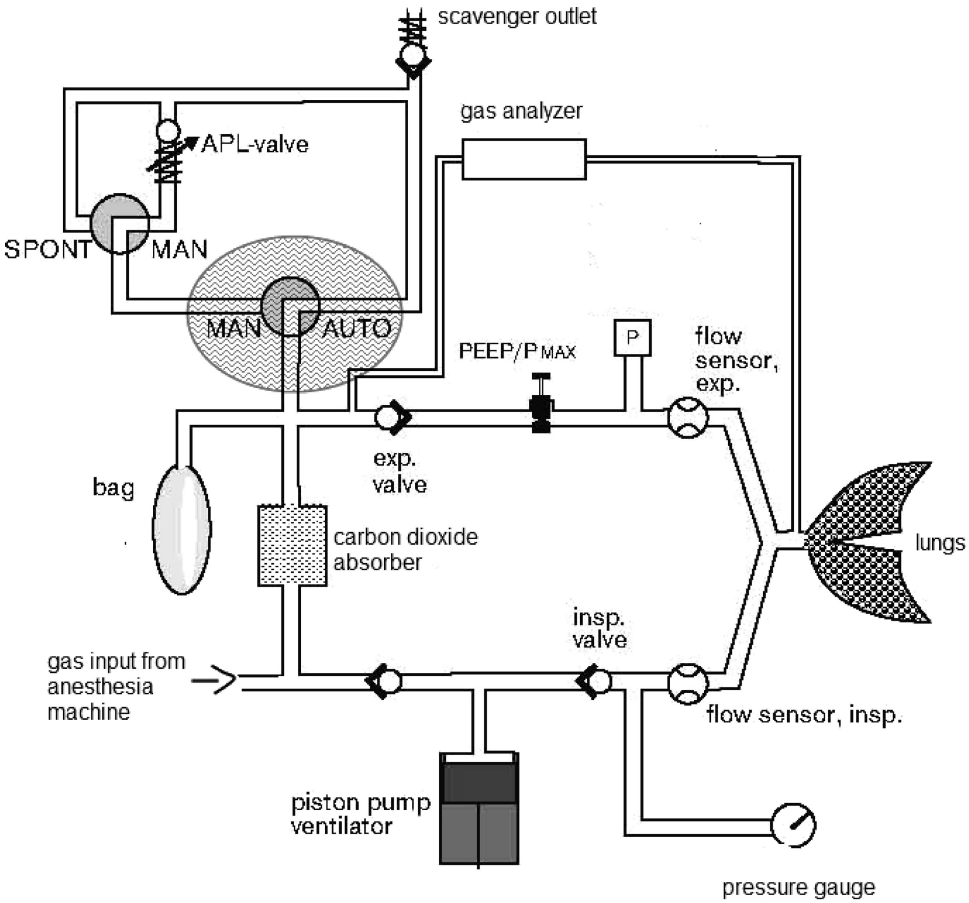

Fig. 1. Gas flow diagram: Dräger Apollo® Anesthesia Workstation. Modified from an original figure in the *Apollo® Operator's Instruction Manual, version 3*. Information furnished courtesy of Dräger. APL = adjustable pressure limitation; AUTO = automatic; exp = expiratory; insp = inspiratory; MAN = manual; P = electronic breathing pressure sensor; PEEP = positive end-expiratory pressure; PMAX = pressure limitation in volume mode; SPONT = spontaneous.

in Germany. Dräger stated they could not find any errors that could explain the failure-to-ventilate problem. They did not specifically mention what the error log might detect in relation to this specific type of problem. Dräger recommended replacing the inspiratory and expiratory flow sensor harness assemblies as well as the analog board and the expiratory sensor in case the problems were related to malfunction of any of the associated components.

We would like to highlight these faults to other users of Dräger Apollo® Anesthesia Workstations. Finally, it is standard practice to have a bag valve mask immediately available, but we would like to emphasize the importance of actually using it. The American Society of Anesthesiologists Recommendations for Pre-Anesthesia Checkout Procedures# recommends requirements for safe delivery of anesthesia care. A specific requirement is "Backup ventilation equipment available and functioning."

Recommendations available at: http://asatest.asahq.org/clinical/FINALCheckoutDesignguidelines02-08-2008.pdf. Accessed January 4, 2011.

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In Reply:

In the letter, the authors discuss three cases pertaining to the Dräger Apollo® Anesthesia Workstation (Dräger Medical Inc., Telford, PA). In two of these cases they describe a nonfunctional manual ventilation at the end of a procedure after an otherwise uneventful mechanical ventilation. In a third case, they describe a nonfunctioning manual ventilation during the induction of anesthesia after previous spontaneous ventilation.