

Schellinger suggested the distance between the upper border of cricoid cartilage and the tip of the xiphoid process correlates well with the length of the airway to the bifurcation of the trachea.⁸ In case of high-pressure jet ventilation, we question whether this is a safe guideline.

Since this episode, we have insisted on direct constant visualization of the proximal black ring on the tube we use (Argyle®, Brunswick Company) which is 9.5 cm away from the distal end during the endoscopic procedure. At the end of each procedure, we recommend that the patient not be ventilated with the jet after the shoulder roll is removed to restore the normal supine position. The pad may be removed and ventilation controlled via mask, while the jet catheter remains in place as an emergency airway.

We again stress that constant vigilance of outflow is necessary with this technique. Laryngeal obstruction of only brief duration can result in high alveolar pressure and lung volume with this technique. This potential is especially high since this technique is most frequently used in situations where edema and/or disease is present in the airway. Both edema and disease were present in this case, and we cannot completely rule out this mechanism, although no obstruction

was evident and chest expansion was symmetrical until the shoulder roll was removed.

We report this case to emphasize that endobronchial intubation is another cause of pneumothorax during high-pressure jet ventilation.

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Failure of Battery-operated Alarms

NORMAN MAZZA, M.D.* AND ALVIN WALD, PH.D.

During the administration of an anesthetic, the anesthesiologist obviously should be certain that the apparatus being used is functioning properly. Cooper *et al.*¹ found that improper or inadequate design of equipment was involved in many of their reported anesthetic mishaps. One approach to help warn of equipment failure has been to devise monitor/alarm systems for anesthesia apparatus. However, these monitor/alarm systems can also fail. For example, Piernan *et al.*² showed that when battery voltage declined, the original electrode biasing circuit for an

oxygen concentration monitor caused an erroneously high reading in the presence of nitrous oxide. Monitors, unchecked or improperly used, can create a hazardous situation by providing the anesthesiologist with a false sense of security.

This report describes the failure of two different battery-operated monitor/alarms: the Instrumentation Laboratories IL 402 Oxygen Alarm Monitor®, and the Dräger D.P.M. Pressure Monitor®.

IL 402 OXYGEN ALARM MONITOR

The purpose of the oxygen alarm monitor is to monitor continuously the inspiratory oxygen concentration and to provide an audiovisual alarm if the oxygen concentration falls below a preselected value. The monitor consists of a polarographic sensor, which is placed in the inspiratory limb of the anesthesia circuit, and appropriate electronics to read and

* Present address: Northern Westchester Hospital Center, Mt. Kisco, New York.

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Address reprint requests to Dr. Wald.

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display the oxygen concentration. The user rotates a dial to select the lower limit of oxygen concentration. If the oxygen concentration falls below the selected limit, an alarm sounds and a red light flashes. The minimum setting is an O₂ concentration of approximately 18 per cent, being set by a mechanical stop.

Prior to the administration of an anesthetic, the IL 402 Oxygen Alarm Monitor was set up as follows: The batteries were checked by rotating the selector switch on the unit to the battery check position. The meter indicated the batteries were good. Then 100 per cent oxygen was passed through the breathing circuit and the oxygen monitor calibrated to read 100 per cent. The sensor was then exposed to room air to ascertain that it read 21 per cent. The values in between were not checked. During this calibration procedure, the alarm was set at its lower limit, which is below atmospheric oxygen concentration. This was done to avoid disturbing an apprehensive patient with the raucous sound of the alarm. Once the anesthesia was under way, the patient received 40 per cent O₂ and 60 per cent N₂O, according to the flowmeter settings and the oxygen monitor reading. The alarm itself was checked by raising the alarm limit to a setting above the indicated 40 per cent. This maneuver should have caused the alarm to activate, but it did not. The alarm failure was found to be due to a dead battery. Further investigation revealed how this occurred in spite of the battery check made prior to use. There are three 4.05-volt mercury batteries in the IL 402. Two of these are used to power the monitor circuitry. The third battery powers only the alarm circuitry. Herein lies the potential danger. The IL 402 battery check feature works on the two circuitry batteries only. In fact, it is possible to calibrate and read oxygen concentration properly with the alarm battery removed.

Occasionally the alarm is not shut off at the end of the day. Since room oxygen concentration is below the usual lower alarm limit, the alarm is activated throughout the entire night. The alarm battery delivers a current of 13 milliamperes for the visual alarm and 6 milliamperes for the audio alarm (alternately). In comparison, the current drains of the two circuitry batteries are 108 and 175 microamperes, as measured on a typical unit. Thus, under this condition, the alarm battery is easily the first to be exhausted.

In fairness to the manufacturer, the instructions for the use of the monitor do state that the alarm should be tested independently during calibration. However, the instructions do not clearly state that the alarm battery is not checked in the battery test mode, and that its failure will not be detected during this test. The audiovisual alarm must be checked separately—by being activated. A functional check not

only tests the battery but also tests the electronic circuitry that controls the alarm. The IL 404 oxygen monitor, which has both high and low alarms, must be functionally checked for both alarm limits.

DRÄGER D.P.M. PRESSURE MONITOR

The Dräger D.P.M. Pressure Monitor is connected to the patient breathing circuit when a ventilator is used. This alarm alerts the anesthesiologist if the ventilator fails to cycle, or if there is a disconnect in the breathing circuit. The alarm has a T-piece that is inserted into the breathing circuit. A length of flexible tubing transmits the breathing circuit pressure from a port on the T-piece to a pressure-sensitive switch in the alarm box. The electronic and alarm circuits are powered by a single 9-volt "transistor"-type battery. There is a momentary-contact battery-test button with a green light-emitting diode "good-battery" indicator. There are three discrete pressure limit settings: 5, 12.5 and 25 cm H₂O. Each time the ventilator increases the pressure in the breathing circuit during an inspiration, a timing circuit is reset. If the pressure in the breathing circuit is below the limit setting for a continuous period of 15 sec, the alarm, a loud sound, and a flashing red light will be activated.

Prior to the start of a case, the alarm T-piece was properly inserted into the inspiratory limb of the breathing circuit, and the battery was checked. The alarm was turned on before mechanical ventilation was started. The alarm did not activate as it should have. The battery test indicator did not show an exhausted battery, but only a subjectively dimmed battery-test light. Replacing the battery resulted in a brighter battery-test light and activation of the alarm.

The battery-test indicator lamp is a light-emitting diode. As the battery voltage declines, light intensity decreases. The condition of the battery is thus somewhat subjective to the observer. We tested a new battery that had a potential of 9.9 volts and delivered a measured current of 12 milliamperes to the test lamp. A battery that had been in use had a potential of 8.5 volts and delivered 7 milliamperes. Although subjective light intensity is difficult to correlate with lamp current, a 14 per cent decrease in battery voltage resulted in a 42 per cent decrease in lamp current.

For normal monitoring without alarm or battery test, the battery drain was measured to be 25 or 30 microamperes. When the alarm was activated, the battery current alternated, due to the intermittent alarm signal, between 11 and 19 milliamperes. At current drains in the microampere range, high-quality alkaline batteries are rated in terms of shelf life.

The 9-volt MN 1604 battery that we use is rated for a 10–15 per cent decrease of ampere hour capacity after one year of storage, and 25 per cent after two years. At a current drain of 20 milliamperes, a typically higher discharge rate, the battery voltage will drop to half in about 30 hours.

Because of the variable conditions of use encountered, it is not possible to specify an absolute quantitative usable life for the battery. We therefore recommend changing the battery every six months. In addition,

we check the batteries and alarm before the start of each operation, as well as at intervals intra-operatively.

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An Unusual Case of Hypercarbia during General Anesthesia

SANFORD L. KLEIN, D.D.S., M.D.,* AND J. KENNETH LILBURN, M.D.†

With the nearly universal application of semiclosed anesthesia systems, the use of carbon dioxide as an adjunct to anesthetic care has been essentially eliminated. Carbon dioxide is still used, however, as an insufflating gas for laparoscopy, and has other minor uses, so it sometimes is supplied from a central source in the operating room. We describe an event in which accidental crossing of central nitrous oxide and carbon dioxide supply systems caused profound hypercarbia in a patient undergoing general anesthesia.

REPORT OF A CASE

A 60-kg, 19-year-old, white female patient was scheduled for emergency total colectomy with a diagnosis of toxic megacolon. Except for the presenting illness, her history was unremarkable. Anesthesia was started with meperidine, 100 mg, iv, thiopental, 250 mg, iv, and pancuronium, 6 mg, iv. Ventilation was controlled, with administration of nitrous oxide, 3 l, oxygen, 2 l, and enflurane, 1–2 per cent. After 5 min, the trachea was easily intubated, after which breath sounds were determined to be equal bilaterally. Five minutes later, arterial blood pressure and heart rate increased from 130/70 to 180/120 torr and from 60 to 160 beats/min, respectively. Additional meperidine, 100 mg, iv, was given. The reservoir bag and carbon dioxide absorber then became warm to the touch. Although esophageal temperature remained normal, the patient became extremely flushed, especially about the head and neck. Enflurane administration was discontinued when systolic

blood pressure suddenly decreased to 80 torr with a heart rate of 140 beats/min. The electrocardiograph showed a widening of the QRS complex. Arterial blood-gas values were: pH_a 7.098, Pa_{CO_2} 116 torr, and Pa_{O_2} 461 torr. The reservoir bag and the carbon dioxide canister were so warm that it was difficult to maintain contact with them. Esophageal temperature, however, remained normal. Hyperventilation with 100 per cent oxygen gradually reduced the flush, hypertension and tachycardia. A thorough search of the immediate area of the machine revealed that the blue nitrous oxide central supply line attached to the back of the machine was interlocked with the central carbon dioxide supply line. Thus, the gas operating the nitrous oxide flowmeter was actually carbon dioxide. The line was inserted into the correct receptacle; nitrous oxide–oxygen–enflurane administration was resumed. After 10 min, repeat analysis of arterial blood gases showed values within normal limits, and the procedure continued uneventfully. The incident had no further ill effect on the patient.

DISCUSSION

Prys-Roberts *et al.*¹ assigned three main causes of gross hypercarbia: 1) inadequate ventilation; 2) re-breathing of exhaled carbon dioxide; 3) supplying exogenous carbon dioxide to the breathing apparatus. Our case clearly falls into the last category. These cases usually entail inadvertent administration of machine-mounted carbon dioxide due to damaged or ignored rotameters.^{2–4} Our case is unusual in that the hypercarbia was caused by crossed central supply lines despite all the usual precautions and fail-safes. All of our central supply gases are brought into the operating room through an Ohio Medical Products® “retractable surgical ceiling column”; connections between the gas lines in the ceiling column and the gas lines mounted on the anesthesia machines are achieved through Ohio Medical Products “Diamond” Quick-Disconnect Adaptors. All of these adaptors are

* Assistant Professor of Anesthesia and Oral Surgery.

† Visiting Assistant Professor of Anesthesia.

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Address reprint requests to Dr. Klein.

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