

# Malfunction of the Expiratory Valve During Spontaneous Ventilation

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*The integrity of inspiratory and expiratory unidirectional valves is very important in the normal functioning of an anesthetic circle breathing system. We describe our experience of an emergency manipulation of a ceramic valve disk of a circle breathing system (Dräger Fabius GS, Dräger Medical Inc) that*

*altered its characteristics and led to rebreathing only during spontaneous ventilation.*

**Keywords:** Ceramic valve disk, expiratory valve, rebreathing.

**T**he integrity of inspiratory and expiratory unidirectional valves (UDVs) is very important in the normal functioning of anesthetic circle breathing system. Here we present a malfunction of the expiratory valve due to a faulty valve disk, leading to rebreathing during spontaneous ventilation on an anesthesia workstation (Dräger Fabius GS, Dräger Medical Inc).

## Case Summary

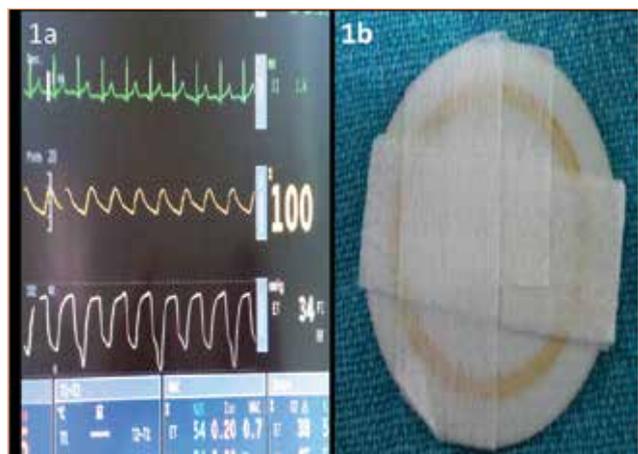
The second surgical case of the day was evacuation of a right temporoparietal extradural hematoma in a 20-year-old man. The patient's Glasgow Coma Scale was E2V2M5 with unequal pupils and left hemiparesis. After the first case, during cleaning of the expiratory valve assembly because of condensation of water on the valve, the ceramic valve disk broke. Since we did not have a spare valve disk immediately and the second surgery was emergent, our anesthesia technician applied adhesive tape (Micropore, 3M) to the broken valve disk and replaced it. The anesthesia machine was checked according to standard guidelines,<sup>1</sup> and the ventilator passed the automated pre-use self-check, which involved calibrating the flow sensor, oxygen sensor, and compliance and leak test of the ventilator circuit. After the machine passed the automated self-check,<sup>2</sup> we connected a test lung to the patient end of the circuit and put the ventilator on volume-controlled mode. We inspected the adequate movement of the inspiratory and expiratory valves and after confirming the proper functioning of the ventilator, we proceeded with the planned emergency surgery to evacuate the hematoma.

After induction of anesthesia, the patient was maintained on volume-controlled ventilation, and the end-tidal carbon dioxide (ETCO<sub>2</sub>) value and waveform were normal in the intraoperative period. Toward the end of the procedure, when the patient was connected to

the spontaneous ventilation mode, we noticed that the ETCO<sub>2</sub> waveform did not touch the baseline, suggesting rebreathing. We increased the flow to 10 L/min, with no change. Then we changed to pressure support ventilation with a frequency of 4, yet rebreathing persisted (Figure 1A). There was condensation of water vapor on the valve disk and not moving adequately during expiration (Figure 1B).

## Discussion

The unidirectional inspiratory and expiratory valves in the circle breathing system is of the turret type, in which the pressure generated by the patient's breathing causes the disk to rise and allow gas to pass in one direction only. Expiratory resistance of the breathing system at a flow of 30 L/min is around 4.8 cm H<sub>2</sub>O.<sup>2</sup> Although modification of the valve disk is not recommended, it was interesting



**Figure 1.** A. Monitor screen showing end-tidal carbon dioxide waveform with baseline shifted up, suggesting rebreathing during spontaneous ventilation. B. Ceramic valve disk with adhesive tape (Micropore, 3M) holding the broken pieces together.

that the pre-use check of the machine did not suggest any malfunction of the expiratory valve disk after our modification; also, the intraoperative period was uneventful. Application of adhesive tape (Micropore) to the broken disk led to increased absorption of moisture, leading to increased weight of the disk and expiratory resistance. During positive pressure ventilation, the pressure generated was adequate to lift the expiratory valve disk, but during spontaneous ventilation the pressure generated by the patient was not enough, so it malfunctioned and led to rebreathing. Although there are previous descriptions of various causes of malfunctioning of the expiratory valve,<sup>3,4</sup> our case describes an emergency manipulation of a ceramic valve disk that altered its characteristics and led to rebreathing only during spontaneous ventilation.

Unidirectional valves in the circle system currently can be tested by the breathing method,<sup>5</sup> the anesthesia machine valve tester (AMVT),<sup>6</sup> capnography, or the modified pressure decline method (MPDM).<sup>7</sup> A problem in UDV's can also be detected by a respirometer located in the expiratory limb upstream to the UDV by indicating reversal of flow when there is an incompetent UDV.<sup>8</sup>

The breathing method involves the clinician exhaling into the inspiratory valve through a corrugated tube while occluding the expiratory port.<sup>5</sup> Inflation of the reservoir bag at the bag mount suggests an incompetent inspiratory valve. Then to test the expiratory valve, the reservoir bag is attached to the expiratory port and the tester exhales through the tubing attached to the bag mount while occluding the inspiratory port. Inflation of the reservoir bag suggests incompetence of the expiratory valve.

The AMVT is a small, self-reinflating pump with a 22-mm connector, and it can deliver positive or subatmospheric pressure.<sup>6</sup> For testing of the expiratory valve, the AMVT is connected to the expiratory port of the ventilator and the bulb is compressed firmly by hand. If the UDV is competent, the compression offers little or no resistance and the bulb remains in the collapsed state as no air passes through the competent UDV.

The MPDM developed by Weigel and Murray<sup>7</sup> involves pressurizing reservoir bags downstream of the UDV's to check for competency. Steps involved in conducting the MPDM are as follows:

1. An extra 3-L reservoir bag is attached to the inspiratory port.
2. Fresh gas flow is minimized, the adjustable pressure-limiting valve is closed, and the circle system is pressurized to 30 cm H<sub>2</sub>O using oxygen flush. A stuck inspiratory valve will prevent bag inflation, and the incompetent expiratory valve will lead to wrinkling of the reservoir bag at the bag mount.
3. The adjustable pressure-limiting valve is opened to decompress the circle system. Wrinkling of the reservoir bag at the inspiratory port indicates an incompetent inspiratory valve.

The situation described here presents a unique dilemma for the attending anesthesiologist. He had to choose between the standard of practice or proceed with the emergency surgery with a modified broken ceramic valve disk, which was found to not hamper the mechanical ventilation during the pre-use self-checkout of the machine before starting the case. In our case, whether the AMVT, MPDM, or respirometer would have detected the incompetent valve during spontaneous ventilation can only be speculative in retrospect.

In our case, once the broken valve disk was identified, we should have replaced it with a new disk rather than modifying it. However, since the replacement was not available immediately and the case was emergent, we resolved to solve this dilemma by repairing the valve disk with adhesive surgical tape. Also, since the valve disk passed the pre-use checkout and the intraoperative period was uneventful, we did not anticipate any problem until there was rebreathing during spontaneous ventilation.

To avoid such a problem, one should always keep a stock of ceramic disk valves for emergency use, and care should be taken while cleaning the valve housing. Furthermore, some anesthesia ventilators have heated breathing systems, which may reduce condensation of water vapor in the expiratory valve housing, thus avoiding the need to clean the valve housing regularly.

## Conclusion

This case describes how manipulation of the critical component of the anesthesia ventilator can lead to problems with ventilation even though the machine passed the pre-use checkout before the case.

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## **DISCLOSURES**

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