An unusual cause of high peak airway pressure: Interpretation of displayed alarms

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ABSTRACT
Airway pressure monitoring is critical in modern day anesthesia ventilators to detect and warn high or low pressure conditions in the breathing system. We report a scenario leading to unexpectedly very high peak inspiratory pressure in the intraoperative period and describe the mechanism for high priority alarm activation. We also discuss the role of a blocked bacterial filter in causing sustained display of increased airway pressure. This scenario is a very good example for understanding the unique safety feature present in the Dräger ventilators and the attending anesthesiologist must have an adequate knowledge of the functioning and safety feature of the ventilators they are using to interpret the alarms in the perioperative to prevent unnecessary anxiety and intervention.

Key words: Anesthesia machine, bacterial filter, breathing circuit, peak airway pressure

INTRODUCTION
Modern anesthesia ventilators with multiple safety features have made the practice of anesthesia safer and easier. Airway pressure monitoring is critical in modern day anesthesia ventilators to detect and warn high or low pressure conditions in the breathing system.[1] We report a scenario leading to unexpectedly very high peak inspiratory pressure in the intraoperative period and describe the mechanism for high priority alarm activation. We also discuss the role of a blocked bacterial filter in causing sustained display of increased airway pressure.

CASE REPORT
A 40-year-old male patient with no comorbid illness was posted for a frontal craniotomy and decompression of tumor. A Dräger Fabius anesthesia machine with reusable silicone reinforced kink resistant circle system was checked according to standard guidelines.[2] Anesthesia was induced with propofol, fentanyl, and vecuronium. After uneventful intubation with an 8.5 mm endotracheal tube, bilateral air entry was confirmed, and lungs were ventilated with 500 mL tidal volume with a peak airway pressure of 15 cm of H2O and maximum pressure (Pmax) set at 40 cm of H2O. After positioning of the patient for craniotomy, we observed that the peak airway pressure rose to 58 cm H2O, with delivered tidal volume of 440 mL, with a plateau pressure of 37 cm H2O [Figure 1a]. The EtCO2 value at that point was 42 mm Hg with normal waveform; there was no reduction in oxygen saturation. On manual ventilation, there was an increase in bag resistance, and on auscultation the breath sounds were equal on both sides. The lungs were easily ventilated with Ambu self-inflating bag (Adult silicone resuscitator, Anaesthetics India Private Limited, Mumbai) without resistance; thus, we ruled out tube kink and obstruction as the cause for increased resistance. At this point, we noted that though EtCO2 value had increased, the up sloping of the phase 2 of the capnogram curve observed during airway obstruction was not seen; instead the EtCO2 curve was normal in appearance. This suggested that the obstruction was not due to bronchospasm, so we sought other causes for an increase in airway pressure. On careful examination of the breathing circuit, we noted that there was crowding of rings of breathing circuit near its attachment with soda lime absorber, and the inner tubing...
was twisted and rotated on itself causing obstruction [Figure 1b]. This probably happened because of rotation of circuit while positioning the patient for skull pins in the supine position. On removing the tension and unwinding the circuit, ventilation was possible, and surgery was completed uneventfully with a new circuit. On examination of the circuit closely, we observed that even with mild rotational force there was a significant reduction in diameter of the circuit leading to partial obstruction [Figure 1c].

**DISCUSSION**

Breathing system obstruction due to kinking of disposable as well as silicone reinforced breathing circuit has been described previously.[3] Also, breathing circuit obstructions mimicking bronchospasm have been reported in the literature.[4] We had checked the hoses of breathing circuit before the case and did not find any abnormality. The single ring might have loosened because of rotation of circuit while positioning the patient for skull pins leading to obstruction.

But, we were intrigued by the fact that why the peak airway pressure should increase to such high level when we have set the pressure limit (Pmax) to 40 cm of H2O. Such high peak airway pressure can lead to barotrauma.[5] In Fabius ventilator, the pressure sensor measures the airway pressure in the inspiratory limb of breathing circuit before the oxygen sensor and the ventilator pressure cannot exceed the set Pmax limit which is a default 40 cm of H2O, because the positive end-expiratory pressure (PEEP)/Pmax valve opens to vent the excess gas in the circuit and the pressure drops. When pressure limit control fails, the high pressure safety valve present in the ventilator will open at approximately 75 cm of H2O.[6]

We analyzed the functioning of the ventilator, as shown in the schematic diagram [Figure 2a]. In the Fabius breathing circuit, pressure is measured in the vicinity of the oxygen analyzer and on the patient side of the inspiratory unidirectional valve (internal pressure sensor). The pressure reading reflects airway pressure only if the circuit is unobstructed between the inspiratory valve and the Y-piece. In our case, the circuit was twisted and partially obstructed between the inspiratory valve and the Y-piece, creating a resistance in series. As a result, during the inspiratory phase of ventilation, the ventilator piston created the high pressure (58 cm H2O) only upstream of the twist in the circuit. This pressure therefore was not true airway pressure and was not the pressure applied to the patient’s airway at the Y-piece. Since the higher resistance of the breathing circuit occurred before the patient’s lungs, the pressure at which air entering the patient’s lungs is much lower. The internal PEEP/Pmax valve – which pneumatically makes sure that no high pressure than the set Pmax pressure enters the lungs is located on the expiratory side of the breathing circuit. Due to this unique safety feature of the Fabius, at no time there was any risk to the patient, despite airway pressure being higher than the set Pmax value of 40 cm H2O.

![Figure 1](image1.png)  
**Figure 1:** (a) Ventilator screen snap shot showing peak airway pressure of 58 cm H2O, with a tidal volume of 440 mL. Also note the plateau pressure of 37 cm H2O. (b) Coiled inspiratory limb of the breathing circuit near its attachment to soda lime canister with a broken ring of the tube. (c) Inside part of the removed breathing circuit after manually twisting showing partial obstruction

![Figure 2](image2.png)  
**Figure 2:** (a) Schematic diagram showing functioning of ventilator with area of obstruction shown. (b) Hose of the pressure monitoring line with filter occluded by an artery forceps. (c) Ventilator screen snap shot showing peak airway pressure of 16 cm H2O, with a set tidal volume of 1000 mL and pressure limiting alarm set at 15 cm H2O. (d) Ventilator screen snap shot after occluding pressure monitoring line showing a peak airway pressure of 27 cm H2O and continuous pressure alarm, with a delivered tidal volume of 378 mL against set 1000 mL.
The reason that Dräger Fabius ventilator showed this higher value, and gave the alarm, was because the internal pressure sensor located at the inspiratory side, measured higher than allowed values. However, due to the unique electronic driven piston ventilator, the nearly whole set volume of 500 mL was delivered, and due to the Pmax valve on the expiratory side, it was pneumatically guaranteed that no higher than set pressure was entering the patient’s lungs. Therefore, a difference between the measured and displayed values of airway pressure, and the actual airway pressure entering the lungs was observed. Intrigued by these set of events we informed the Dräger Company regarding this event and expressed our concern regarding sustained elevation of increased peak airway pressure. The service engineer provided the above discussed mechanism for display of such high airway pressure and decided to simulate the same in their laboratory. They were only able to simulate such high peak pressures occurring on the Fabius screen (Dräger Medical AG & Co. KG, Lubeck, Germany), by creating the occlusion manually in the pressure sensor line. The company also reported that the increased airway pressure were not as high as in our case and the increased airway pressure displayed in the monitor occurred only for a brief period at a certain occlusion pressure, and in most of the cases the Fabius internal control mechanism already limited the peak inspiratory pressure, so that such high pressure never have been able to show up on the display. The high peak pressures occurred only when they completely blocked the filter in the pressure measuring line. Following the feedback from Dräger based on their analysis from simulation at their laboratory, we retrospectively examined the pressure monitoring line and the bacterial filter (which was replaced with a new one) in our anesthesia ventilator and found a blackish membrane blocking the inlet compared with a new bacterial filter. We tried to simulate the event in a different ventilator where we decreased the set Pmax limit to 15 cm H₂O and increased the set tidal volume to 1000 ml leading to a decrease in delivered tidal volume to 409 mL at the same time pressure limiting to 16 cm H₂O [Figure 2c]. We then partially blocked the pressure monitoring line connecting the bacterial filter with an artery forceps [Figure 2b] and we could see that there was a continuous pressure alarm in the ventilator monitor and the peak pressure initially rose up to 30 cm H₂O and decreased to be maintained at 27 cm H₂O which was 12 cm H₂O more than the set limit [Figure 2d] confirming the observation by the Drager company also. Dräger service engineer changes the filter during our annual service of the machine according to the company service policy and there are no recommendations on changing the bacterial filter present in the pressure monitoring line. After this incidence, we regularly examine bacterial filter in the pressure monitoring line and change it every 6-month period.

CONCLUSION

This scenario is a very good example for understanding the unique safety feature present in the Dräger ventilators and the attending anesthesiologist must have an adequate knowledge of the functioning and safety feature of the ventilators they are using to interpret the alarms in the perioperative to prevent unnecessary anxiety and intervention. Furthermore, the root cause for the displayed high peak pressure was not only the kinked inspiratory limb of the breathing tube, but also a blocked pressure measuring line by an occluded filter.

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