

## Think beyond the circuit: Flow sensor malfunction as a cause of an anesthesia system leak

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### ABSTRACT

Leaks during anesthesia can lead to life-threatening situations in the operating theatre (OT). We present a case, in which the pre-use checklist was completed before the start of the OT, but a massive leak in anesthesia system was encountered during the third case of the day, while the two preceding cases had proceeded uneventfully. Despite extensive efforts, the source of the leak could not initially be identified. A workstation technician was called, and on disassembling the workstation, a broken tube connecting the flow sensor to the workstation information system within the compact breathing system was identified. As we were unaware of this concealed but accessible component, we were initially unable to identify the source of the leak. Anesthetists should be familiar with this component of the anesthesia workstation to facilitate prompt recognition and management of such leaks and thereby reduce the risk of hypoventilation, hypoxia, and other complications associated with anesthesia system leaks.

**Key words:** Anesthesia leak, Compact breathing system assembly, Flow sensor

Patient safety is of paramount importance during anesthesia. Completion of the pre-use checklist is essential before administering anesthesia. Despite these checks, equipment leaks continue to be reported. Leaks within the anesthesia machine and breathing system account for 9.6% of incidents during anesthesia, of which 5.1% are related to the vaporizer and 1.9% to the gas supply to the machine. The most common sites of leakage are the low-pressure system, breathing system, and area around the endotracheal tube [1].

Although advances in patient monitoring and automated checking functions in modern anesthesia machines help prevent many problems, it is still necessary to be familiar with the appropriate pre-use inspection procedures for anesthesia equipment [2,3]. Intraoperative vigilance by anesthesia personnel is equally essential to prevent anesthesia-related mishaps.

We present a case, in which, despite completion of the pre-use checklist, a massive leak developed in anesthesia system during the latter half of the day, with no visible or audible source of leakage, while two previous surgeries had proceeded uneventfully on the same anesthesia workstation.

### CASE HISTORY

A 30-year-old woman attended the pre-anesthetic check-up clinic and was scheduled for laparoscopic cholecystectomy. She had no significant past medical or surgical history. Airway examination revealed adequate mouth opening with a modified Mallampati grade II airway. All blood investigations were within normal limits. She was kept nil per oral according to standard fasting guidelines, and informed consent was obtained. The patient was classified as American Society of Anesthesiologists physical status I, with all pre-operative investigations within normal limits.

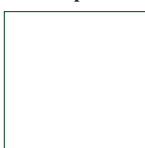
The operating theater (OT) was prepared, and anesthesia workstation was checked for leaks before the procedure; no leak was detected. This was the third case of the day, and the first two cases had been completed uneventfully in the same OT.

General anesthesia was induced with propofol 120 mg intravenously after premedication with fentanyl 100 µg intravenously. After adequate ventilation was confirmed, vecuronium 5 mg intravenously was administered. Three minutes later, a ProSeal LMA No. 3 was inserted, and correct placement without leakage was confirmed. The patient was then placed on volume-controlled ventilation with a fresh gas flow of 2 L/min.

#### Access this article online

Received - 05 August 2026  
Initial Review - 21 August 2026  
Accepted - 08 September 2026

#### Quick Response code



DOI: \*\*\*

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After the patient had been positioned, the anesthesia workstation was slightly moved toward the head end by the technician to provide adequate operative space for the surgeon. Immediately thereafter, the capnographic waveform became untraceable on the monitor. Simultaneously, all other ventilatory parameters disappeared from the screen, and the ventilator bellows collapsed.

The patient remained hemodynamically stable. She was immediately switched to manual ventilation, but the reservoir bag did not fill. We switched to the common gas outlet with a Bain's circuit attached. The patient could then be ventilated, with visible chest rise and restoration of capnographic waveforms. All connections were rechecked, and any visible or audible source of leakage, equipment damage, and other possible causes were ruled out.

We were unable to identify the cause of the sudden leak in the closed circuit, so the designated company engineer was called. The engineer inspected the workstation but did not identify any visible source of leakage. The compact breathing system of the workstation was then disassembled, revealing a small broken tube connecting the flow sensor in the expiratory limb to the workstation information system (Fig. 1). The tubing was probably pulled when the machine was moved, resulting in fracture of part of the flow-sensor assembly (Video 1).

After replacement of the flow sensor, the leak was resolved and the surgery was completed. At no point was patient safety compromised.

## DISCUSSION

Ensuring completion of the pre-use checklist is a vital prerequisite before administering anesthesia. Despite these precautions, equipment leaks may still occur. Leaks within the anesthesia machine and breathing circuit contribute to 9.6% of anesthesia-related incidents, with most arising from the vaporizer and gas supply system. The most frequent sites of leakage include the low-pressure system, breathing system, and region around the endotracheal tube. Although modern advances, such as improved patient monitoring and automated safety checks integrated into newer anesthesia machines, have reduced the occurrence of such problems, comprehensive knowledge of

appropriate pre-use equipment inspection remains indispensable. Therefore, a pre-use leak test should be performed before initiating anesthesia [4].

Leaks in the anesthesia circuit can lead to hypoxia, hypoventilation, inadequate delivery of inhaled anesthetic gases, and contamination of the operating room. They may result from disconnection or damage to the breathing circuit [5]. Clinical indicators of a leak include an audible leak, collapse of the breathing bag or ventilator bellows, inability to ventilate, a decrease in oxygen saturation, a fall in end-tidal carbon dioxide, reduced tidal volume, and decreased airway pressure [5,6].

A leak may occur during anesthesia despite completion of the pre-use checklist. Timely identification can be facilitated by observing the absence of chest rise, loss of capnography, loss or reduction in tidal volume, changes in peak airway pressure, and a decrease in oxygen saturation. An anesthetist must respond immediately by restoring ventilation and identifying and correcting the site of the leak. Initial measures to establish ventilation include manual ventilation, switching to an open circuit or auxiliary flowmeter, using a wall-mounted flowmeter, using an Ambu bag, changing the airway device or tube when appropriate, and bag-mask ventilation. The anesthetist should then check for workstation alarms related to gas supply, disconnections from the patient end to the workstation and pipeline, adequate cuff inflation when applicable, audible hissing, and any possible site of damage, considering the sequence of events immediately preceding the leak.

Kishimoto *et al.* reported a case, in which a leak was caused by tearing of the circuit while engaging the tube in a tube holder [5]. Nandwana *et al.* reported an intraoperative leak caused by damage to the anesthesia circuit from a hooked towel clip forceps beneath the drapes [7]. Leakage due to flow-sensor malfunction has also been reported. Hari *et al.* described a situation, in which capnographic tracings and ventilatory parameters were lost, and a fracture of the ventilator flow sensor was subsequently identified [8]. Similarly, Kojima *et al.* reported loss of ventilatory parameters on the ventilator screen due to disconnection of the hot-wire anemometer in the flow sensor [9]. Kumari *et al.* reported a circuit leak caused by damage from a tube holder [10].

In an anesthesia workstation, the flow sensor and its associated tubing may not be readily visible during routine inspection. However, they can be a source of significant leakage, as occurred in our case. In our patient, the workstation was slightly moved by the technician in the presence of anesthetist, after which the leak developed. We were able to identify the problem promptly and maintain ventilation because of the immediate response. However, we initially failed to identify the source of the leak because we were unfamiliar with the location, assembly, and attachments of the flow-sensor system. The experience illustrates the principle that “the eyes cannot see what the mind does not know.” Once the flow-sensor assembly was

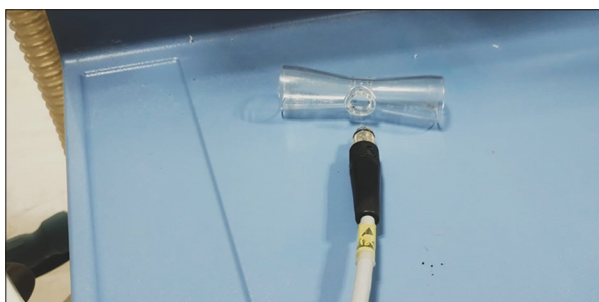


**Figure 1:** Broken part of the flow-sensor assembly (small tubing) connecting the flow sensor in the expiratory limb to the workstation information system

recognized, it could be readily disassembled and the damaged component replaced.

## CONCLUSION

In addition to completing the pre-use checklist for the anesthesia workstation, anesthetists should be familiar with less visible but accessible potential sites of leakage. In the event of sudden massive leakage during an ongoing procedure, the flow-sensor assembly should be considered as a possible source. Early recognition is possible when the location and configuration of this component are known, allowing prompt correction and restoration of safe ventilation.

## ACKNOWLEDGMENT

The authors express their gratitude to Prof. Kausik Maji, MD, Prof. C. N. Gupta, MD, and all the colleagues and staff of the Department of General Medicine, IIMSAR and Dr. B. C. Roy Hospital, Haldia, West Bengal, and especially to the patient and her relatives for their guidance and cooperation.

## PATIENT CONSENT

Written informed consent was obtained from the patient for publication of the case report and associated clinical images/video, as applicable.

### Video 1: Demonstration of the broken flow-sensor tubing

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*Funding: Nil; Conflicts of interest: Nil.*

**How to cite this article:** Agrawal P, Mudgal P, Singh R. Think beyond the circuit: Flow sensor malfunction as a cause of an anesthesia system leak. *Indian J Case Reports*. 2026; October 06 [Epub ahead of print].