A Persistently High End-Tidal Carbon Dioxide Value: Can This Be Spurious?

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Abstract
End-tidal carbon dioxide (EtCO2) monitoring has now become the standard of care not only during anesthesia but also in intensive care units for patients on mechanical ventilation, emergency department, and pre-hospital settings to confirm and monitor the correct placement of endotracheal tube. It is a non-invasive and continuous method of measuring exhaled carbon dioxide (CO2). Continuous waveform capnography measures EtCO2 and monitors ventilation. EtCO2 often correlates with partial pressure of carbon dioxide in arterial blood (PaCO2) and is a reliable indicator of PaCO2. A rise in EtCO2 often implies increased production of CO2 or decreased excretion (rebreathing, decrease ventilation) of CO2. We report an unusual case where the monitor malfunction per se lead to spuriously increased EtCO2 values without any clinical cause and did not correlate with PaCO2, thereby re-emphasizing that various monitors must always be interpreted in correlation with clinical observation.

Keywords
- end-tidal carbon dioxide
- monitor malfunction
- anesthesia
- capnography

Introduction
End-tidal carbon dioxide (EtCO2) monitoring is considered standard of care during anesthesia, in mechanically ventilated patients in intensive care unit and in pre-hospital settings to confirm correct placement of endotracheal tube (ETT).1 Apart from the advantages of being a continuous and non-invasive monitor of exhaled carbon dioxide (CO2), it is also a reliable indicator of partial pressure of CO2 (PaCO2) in arterial blood and is often used as its surrogate.2 Changes in EtCO2 and PaCO2 normally parallel each other and the difference between the two is approximately 3.6 to 4.6 mm Hg in healthy awake patients.3 We report a case where EtCO2 values were disproportionately high and did not correlate with PaCO2.

Case Presentation
A 62-year-old female patient weighing 59 kg was diagnosed with L5–S1 listhesis and was planned for surgery. She was a known hypertensive, controlled on amlodipine (5 mg daily) for last 7 years. On pre-anesthetic check-up, she had bilateral wheeze and was optimized with corticosteroid, and bronchodilator nebulization for 1 week before surgery. Her preoperative investigations including pulmonary function tests were within normal limits. In the operating room, peripheral intravenous access was established, and routine standard monitoring was started (electrocardiography, non-invasive blood pressure, pulse-oximeter, and sidestream capnography). After preoxygenation with 100% oxygen for 3 minutes, general anesthesia was induced with intravenous fentanyl 120 µg and propofol 140 mg. Rocuronium 50 mg was given to facilitate tracheal intubation, and the patient was ventilated with bag and mask for 3 minutes. While manually ventilating the patient, the multichannel monitor displayed a high EtCO2 value (70–80 mm Hg, Fig. 1A). Suspecting this to be due to inadequate mask ventilation, trachea was intubated and ETT position was confirmed by capnography and auscultation. Anesthesia was maintained with sevoflurane in O2:N2O (40:60) mixture. The EtCO2 value remained high (90–100 mm Hg, Fig. 1B) and kept rising constantly. Despite all measures to decrease EtCO2 including increasing minute ventilation (up to 13 L/min), reconfirming ETT position, increasing fresh gas flow, use of fresh CO2 absorbent,
change of sampling tube and manual ventilation, EtCO₂ value kept increasing gradually and reached up to 113 mm Hg (**Fig. 1C**). An arterial blood gas (ABG) analysis was performed which showed a PaCO₂ value of 28 mm Hg with all other parameters within normal range, thus, indicating a probability of monitor malfunction and spuriously raised EtCO₂. The monitor was then replaced with a new monitor, which showed an EtCO₂ value of 26 mm Hg with same ventilator settings (**Fig. 1D**).

**Discussion**

End-tidal carbon dioxide is the real-time monitoring of exhaled CO₂ over time that can be measured using either mainstream or sidestream capnometers with few inherent advantages and disadvantages of each type. EtCO₂ is often used as a surrogate for PaCO₂ in mechanically ventilated patients. Changes in EtCO₂ normally parallel changes in PaCO₂. However, there are several clinical situations where EtCO₂ values can be raised or decreased.

Sensor windows of mainstream capnometers or sampling line of sidestream capnometers are both prone to clogging by secretions, aerosols, or water droplets. Erroneous EtCO₂ readings, such as sudden drop in EtCO₂ due to obstruction of sampling tube leading to incorrect interpretation of venous air embolism or large pulmonary embolus, have been reported in literature. Simple maneuvers, such as purging the sampling line with a syringe to dislodge water droplets in the tubing, replacing the sensor, or sampling tube can correct any artefactual changes in EtCO₂ and avoid further unnecessary interventions. At low sampling rates with long sampling catheters, the expired CO₂ gas is subjected to axial mixing and dispersion during its transit through the catheter, leading to underestimation of measured CO₂ value. Even a broken male Luer connector of the sampling tube and placement of a jet nebulizer between the mainstream capnometer and ET tube have been reported to cause reduced EtCO₂ values.

On the other hand, causes of high EtCO₂ can be broadly classified as those due to decreased excretion and due to increased production and iatrogenic causes. Decreased excretion can be due to increased inspired CO₂, decreased ventilation, or increased dead space. Problems with anesthesia machine, such as exhausted soda lime, faulty inspiratory or expiratory valve, and channeling through soda lime can increase inspired CO₂ causing high EtCO₂. Inadequate ventilation can occur due to leaks in the circuit, bronchospasm, endobronchial intubation, and partial airway obstruction due to kink or mucus plug. Increased production of CO₂ due to fever, shivering, convulsions, hyperthyroidism, burns, malignant hyperthermia (MH), and rarely, pheochromocytoma and transfusion reaction can cause high EtCO₂. Iatrogenic causes include CO₂ insufflation during laparoscopy, tourniquet release, and infusion of sodium bicarbonate. Further, false or spurious increase in EtCO₂ can occur due to monitor malfunction or calibration error. In our patient, inspired CO₂ values were within normal limits (fractional inspired [FiCO₂]: 1–2), CO₂ absorbent was fresh, and there were no leaks in the circuit. Expiratory unidirectional valve malfunction such as...
valve breakage\textsuperscript{9} or misplaced metal retainer\textsuperscript{10} can result in raised EtCO\textsubscript{2} values due to rebreathing of exhaled air and manifest as increase in both inspired and expired segments of EtCO\textsubscript{2} waveform. However, in our case inspired CO\textsubscript{2} values were always within normal limits. Channeling is difficult to detect but is treated by replacement of soda lime. Hypoventilation was an unlikely cause in our patient as expired tidal volume and blood oxygen saturation were normal. On auscultation, bilateral air entry was equal ruling out endobronchial intubation. Airway pressure was normal, chest was clear, suctioning of the ET\textsubscript{T} was clear, and there was no delayed upstroke in EtCO\textsubscript{2} waveform; so, bronchospasm and partial ETT obstruction seemed unlikely. Our patient’s temperature was normal, ruling out fever as a possible cause. It is not possible to detect clinical seizures or shivering in a paralyzed and mechanically ventilated patient. Burns are self-evident; sometimes result in fallacious EtCO\textsubscript{2} readings and it should always be interpreted in correlation with clinical observation.

In healthy subjects, EtCO\textsubscript{2} and PaCO\textsubscript{2} generally correlate well. PaCO\textsubscript{2} values are generally 2 to 5 mm Hg above EtCO\textsubscript{2} values. However, in conditions of increased physiological dead space, the correlation between end-tidal and arterial CO\textsubscript{2} is poor. With increased physiological dead space, there is mixing of gas from poorly perfused areas of lung with that from well-perfused areas, resulting in a lower EtCO\textsubscript{2} relative to PaCO\textsubscript{2}.\textsuperscript{11} In our case, though the gradient was widened, the change was in the reverse direction, EtCO\textsubscript{2} being much higher relative to PaCO\textsubscript{2}. An increase in physiological dead space could not have explained this discrepancy. A fault with the monitor or a calibration error was the only possible cause.

The manufacturing company of the monitor was contacted to detect and rectify the fault in the monitor. The service engineers tested and recalibrated the equipment. However, discussion with service engineer did not yield anything specific. Subsequent use of the monitor after recalibration displayed correct EtCO\textsubscript{2} values, which correlated with PaCO\textsubscript{2} values.

**Conclusion**

Our case highlights that monitor malfunction per se may sometimes result in fallacious EtCO\textsubscript{2} readings and it should always be seen as a possibility if no other cause is found before undertaking extensive interventions. It re-emphasizes the fact that various monitors used under anesthesia must always be interpreted in correlation with clinical observation.

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**Conflict of Interest**

None declared.

**References**