J Clin Monit Comput (2018) 32:369–371
DOI 10.1007/s10877-017-0002-6

LETTER TO THE EDITOR

An abrupt reduction in end tidal carbon di oxide concentration in a mechanically ventilated patient in neurocritical care ward: a capnogram artifact

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Received: 6 December 2016 / Accepted: 8 February 2017 / Published online: 21 February 2017

Abstract In patients with normal lung and reasonable cardiac function such as head injury patients, the $PETCo_2$ can be used as a surrogate for partial pressure of Carbon dioxide ($PaCO_2$) in mechanically ventilated patients. Thus early interpretation and accurate assessment of capnogram is crucial in neurocritical care patients. Here we present and discuss a scenario where in connection of a jet nebulizer to the ventilator lead to abrupt decrease in end tidal carbon dioxide leading to a diagnostic dilemma. Also this report highlights and discusses the importance of the proper placement of breathing circuit components to ensure accurate CO_2 readings in particular the use of a jet nebulizer.

Keywords Capnogram · Nebulization · Jet Nebulizer · False low end tidal carbon dioxide

1 Introduction

Capnography measures the levels of excreted carbon dioxide (CO_2) into the blood stream. End tidal CO_2 ($PETCo_2$) is the partial pressure or maximal concentration of CO_2 at the end of expiration [1]. In patients with normal lung and reasonable cardiac function such as head injury patients, the $PETCo_2$ can be used as a surrogate for partial pressure of CO_2 ($PaCO_2$) in mechanically ventilated patients [2]. Intensive care society capnography guidelines updated in 2015 recommend continuous capnography monitoring in all ventilated ICU patients [3]. Thus early interpretation and accurate assessment of capnogram is crucial in neurocritical care patients. We present and discuss a capnogram artifact in an adult head injury, mechanically ventilated patient.

2 Case Detail

A 46 year old male patient with no co-morbidities was admitted to neuro-critical care ward after left front temporal decompressive craniotomy for acute sub dural haemorrhage. With an admission Glasgow Coma Score (GCS) of $E_1V_1M_5$ he was immediately intubated and transported to the operating room. Post surgery his GCS was $E_1V_t M_5$ and he was shifted to ICU for further management. In the ICU the brain protection strategy followed included maintaining mean arterial pressure >70 mm Hg, head end elevation to 30°, hyperosmolar therapy with mannitol and maintaining the $PETCo_2$ in the range of 30–35 mm Hg. On day 2 of his ICU stay the nurse informed the physician of the low $PETCo_2$ alarm on the patient monitor. On observation the $PETCo_2$ was 21 mm Hg, haemodynamically stable and there was no recent change in ventilator settings (*MAQUET, Servo i, Sweden*). (Fig. 1a) But on careful enquiry we noted that (a) the event occurred after the nurse connected the jet nebulizer (Cirrus ^{TM} *2 nebulizer with 22 mm T piece kit and tube, Intersurgical, UK*) in the patients breathing circuit between the main stream capnometer and the tracheostomy tube (Fig. 1b) (b) the $PETCo_2$ value returned to 34 mm Hg (Fig. 1c) after disconnecting the nebulizer from the patient circuit.

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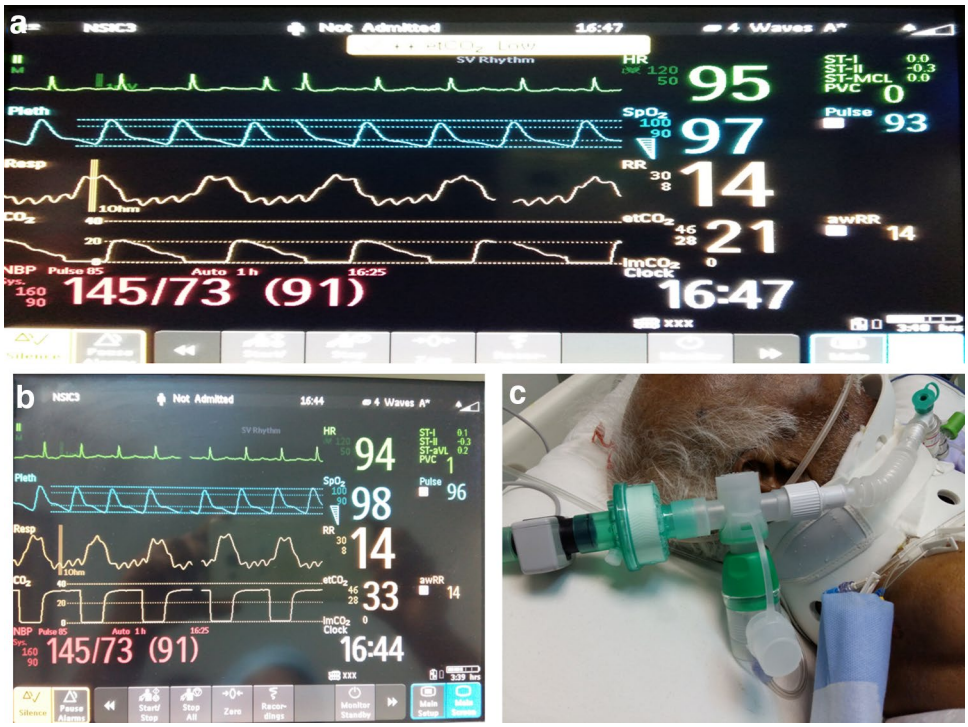

Fig. 1 Snapshot of the patient monitor with stable haemodynamics. Decreased $PETCo_2$ to 21 mm Hg from a base line of 34 mm Hg. The capnograph waveform shows normal phase I and II, but there is gradual decrease of the phase III to baseline leading to decreased PETCo2 value. Snapshot of the patient monitor after disconnecting the jet nebulizer from the ventilator circuit. We can see the normal capnogram waveform with stable haemodynamics. Image showing the location of jet nebulizer between the main stream capnometer and the tracheostomy tube

3 Discussion

Capnography is not used widely in ICU compared to its use in operation theatre. Only 25% of intensive care units in UK use capnography for the continuous monitoring of mechanically ventilated patients as of 2009 [4]. According to the national patient safety agency (NPSA) database approximately 500 patient safety incidents associated with the use of airway devices occurred in ICUs every year of which 10% are associated with more than temporary harm [5]. It is important to observe that though the disconnection or accidental removal of a tracheostomy or endotracheal tube can be easily recognized by the ventilator alarm, the partial dislodgement of the ventilator circuit especially when changing patient's position or during airway procedure can be easily identified by capnogram morphology [6].

With the main stream capnometer (*Philips M2501A Mainstream Co $_2$ sensor, Einthoven, Netherlands*) used in our case, a sample cell is connected directly between the breathing circuit and the tracheostomy tube. Given our concern with the possible obstruction by condensation of water and accumulation of secretions on the windows in the sample cell we placed the sensor distal to the heat moist exchanger (HME). It is known that with a sudden abrupt fall in $PETCo_2$ due to venous air embolism/ pulmonary thrombo-embolism/decreased cardiac output [7] capnogram morphology is preserved i.e., all the four phases are identifiable. But in this case along with the abrupt fall in $PETCo_2$ to 22 mm Hg from a baseline of 34 mm Hg there was a gradual change of phase III of capnogram to zero. Also in our case there were no associated clinical signs such as a fall in blood pressure, oxygen saturation or no recent changes in ventilatory settings.

The reason for this capnogram artifact can be explained by connection of the jet nebulizer between the capnometer and tracheostomy tube, leading to the dilution of expiratory gases by the forward flow of fresh gas flow (oxygen) at 10 L/min. This occurs during the latter part of expiration when there was a decline in expiratory flow rate below forward fresh gas flow leading to a gradual decrease of the phase III of the capnograph to base line and a falsely low $PETCo_2$ value. Additionally, it is important to understand that this dilutional effect varies throughout the expiratory cycle and can be quantified by observing the expiratory flow waveform. From this it can be observed that the peak expiratory flow values relative to the jet nebulizer flow occur at the start of expiration versus the minimal flow at the end which results in nearly no CO_2 being "seen" in the sample cell of the mainstream sensor.

It is important to note that jet nebulizers are the commonly used device for nebulization during mechanical ventilation as they are simple to use and cost effective [8, 9]. Since the operation of jet nebulizer requires a gas flow of 6–8 L/min they can interfere with the tidal volume delivered by the ventilator [10]. To overcome these problem jet nebulization systems may be integrated into modern ventilators which by synchronizing delivery of nebulization

with inspiration reduce the loss of aerosolized medication during expiration and provide precise delivery of tidal volumes thus avoiding use of external gas source for providing nebulization [11].

Prolonged prophylactic hyperventilation with $PaCo_2 \leq 25$ mm Hg is not recommended as it can lead to cerebral ischemia. Since $PETCo_2$ can be used as a surrogate for $PaCO_2$ the continuous monitoring of capnogram can help maintain eucapnia in head injury patients and help decrease the utilization of arterial blood gas analysis to determine $PaCO_2$. Continuously monitoring $PETCo_2$ in head injury patient on mechanical ventilation will help avoid hyperventilation.

4 Conclusion

This report highlights the importance of the proper placement of breathing circuit components to ensure accurate CO_2 readings in particular the use of a jet nebulizer. The addition of nebulizer between the mainstream capnometer and the endotracheal tube can lead to falsely low $PETCo_2$. values. It is critical for the clinician to be able to see the capnogram in order to better troubleshoot situations such as this.

Thus the clear understanding of the waveform morphology can help avoid confusion by differentiating this scenario from other life threatening conditions causing abrupt low $PETCo_2$ such as pulmonary thrombo-embolism/ decreased cardiac output and help maintain eucapnia.

Compliance with ethical standards

Conflict of interest The current work has been done with institutional resources and the author has not received any financial support for the work. The author does not have any conflict of interest in the material.

Informed consent Written informed consent obtained.

References

1. Scott E, Brient JJ, Van der Aa JS, Gravenstein D, Sosos MB. Respiratory gas monitors. In:Sosis MB, Anesthesia equipment manual. 1st ed. Philadelphia: Lippincott-Raven; 1997. pp. 158–61.
2. Thompson JE, Jaffe MB. Capnographic waveforms in the mechanically ventilated patient. Respir Care. 2005;50:100–8.
3. Faculty of Intensive care Medicine and the Intensive care society. Guidelines for the provision of Intensive care services. London 2015.
4. Cook TM, Woodall N, Harper J, Benger J. Fourth Nation Audit P. Major complications of airway management in the UK: results of the fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. Br J Anaesth 2011;106:632–642.
5. Thomas AN, Mcgrath BA. Patient Safety incidents associated with airway devices in critical care: a review of reports to the UK National Patient Safety Agency. Anaesthesia. 2009;64:358–65.
6. Whitaker DK. Time for Capnography- everywhere. Anaesthesia. 2011;66:544–9.
7. Kodali BS; 2014. Available at: WWW. Capnography.com [Accessed 26 November 2016].
8. Ehrmann S, Roche-Campo F, Sferraza Papa GF, Isabey D, Brochard L, Apiou-Sibrlea G. Aerosol therapy during mechanical ventilation: an international survey. Intensive Care Med. 2013;39(6):1048–56.
9. Dolovich MB, Dhand R. Aerosol drug delivery: developments in device design and clinical use. The Lancet. 2011;377(9770):1032–45.
10. Dhand R. Aerosol delivery during mechanical ventilation: from basic techniques to new devices. J Aerosol Med Pulm. Drug Deliv. 2008;21(1):45–60.
11. Ehrmann S, Lyazidi A, Louis B, Isabey D, Le Pennec D, Brochard L, Apiou-Sbirlea G. Ventilator-integrated jet nebulization systems: tidal volume control and efficiency of synchronization. Respir Care. 2014;59(10):1508–16.