Indian Journal of Trauma and Emergency Pediatrics
Volume 5 Number 2, April - June 2013

End Tidal Carbon Di Oxide (PET CO_2) Monitoring

Lakshmi Muthukrishnan*, Radhika Raman**

Abstract

End-tidal carbon dioxide monitoring is useful in the prehospital setting, emergency department, intensive care unit, and operating room. Monitoring capnography/capnometry is the single most useful method and is recommended to confirm proper endotracheal tube position. It has a variety of clinical applications in critically ill pediatric patients.

Key words:Capnograhy; Pediatric; Emergency;Uses.

Introduction

Monitoring of exhaled carbon dioxide through the respiratory cycle is known as capnography. Though pulse oximetry is a widely accepted procedure for respiratory monitoring, it does not measure carbondioxide which represents ventilation. Capnography is more reliable than pulse oximetry in early detection of respiratory depression. Capnography directly measures the ventilatory performance of the lungs and indirectly presents measurements on the performance of metabolism and circulation. For example, an increased metabolism will increase the production of carbon dioxide increasing the $ETCO_2$. A decrease in cardiac output will lower the delivery of carbon dioxide to the lungs, decreasing the $ETCO_2$. Thus, it gives us a rapid and reliable method to detect life-threatening conditions such as malposition of tracheal tubes, ventilatory failure, circulatory failure and defective breathing circuits.[1]

Author Affilation: *Post doctoral fellow in Pediatric Emergency Medicine, Junior consultant in Pediatric Emergency Medicine, Kanchi Kamakoti CHILDS Trust Hospital, Chennai, **Senior consultant in Pediatric emergency, KKCTH & CTMRF.

Reprint Request: Dr. Lakshmi Muthukrishnan, Kanchi Kamakoti CHILDS Trust Hospital, 12-A, Nageswara road, Nungambakkam, Chennai 600034.

E-mail: vcmlck@yahoo.co.in

Definitions

Capnography

A graphic display of instantaneous CO_2 concentration (FCO_2) versus time or expired volume during a respiratory cycle (CO_2 waveform or capnogram)

Capnometry

The measurement and display of carbon dioxide (CO_2) on a digitial or analogue monitor.

Capnograms

CO_2 waveforms which may be of two types: FCO_2 can be plotted against expired volume (volume capnogram) or against time (time capnogram) during a respiratory cycle.

$PETCO_2$

Partial pressure of CO_2 at the end of expiration.

$PaCO_2$

Partial pressure of CO_2 in arterial blood.

$PACO_2$

Partial pressure of CO_2 in the alveoli.

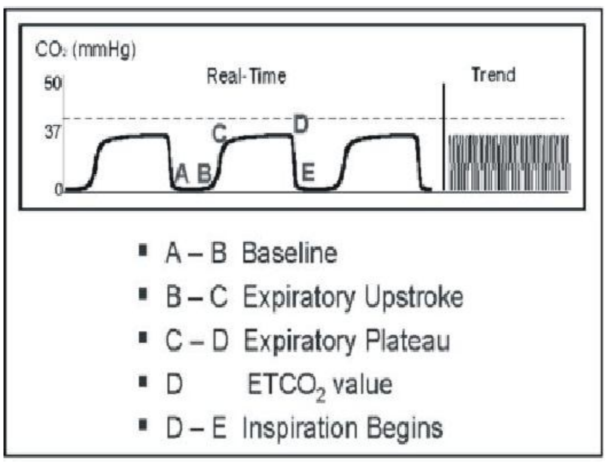
$(a\text{-}ET)PCO_2$

Arterial to end-tidal CO_2 tension/pressure difference or gradient. The normal $PaCO_2$-$PETCO_2$ gradient is about 5 mmHg.

$ETCO_2$

The maximum PCO_2 at the end expiration (point D) in a capnogram is displayed as a numerical value, called the end-tidal PCO_2 ($PETCO_2$). The values vary between 35 and 40 mmHg.

Measurement and Physiology

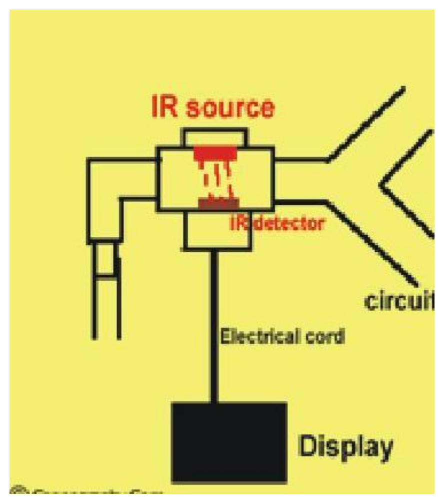


Infrared technology is by far the most common and cost-effective method of carbon dioxide measurement and monitoring.[2] Efforts have been made to decrease the response time and increase the accuracy of infrared technology to produce superior capnography waveforms even in premature babies with small tidal volumes and rapid respiratory rates.[3] The carbon dioxide values are usually displayed as partial pressure (PCO_2).

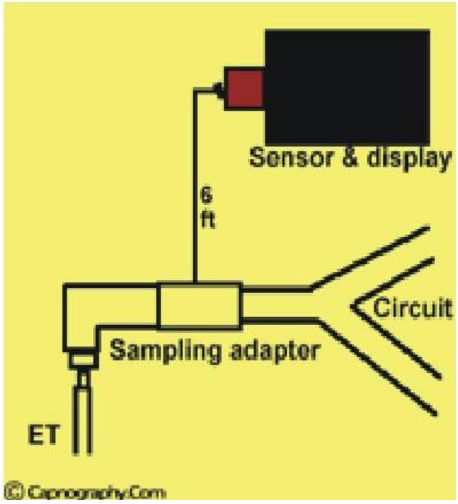
Time Capnogram

Time capnography is used more commonly in clinical practice. A time capnogram has two important segments: inspiratory and expiratory.

Depending on the location of the carbon dioxide measuring device, there are two sensor types: mainstream and sidestream.



Main-stream Capnographs	
Advantages	**Disadvantages**
No affect due to pressure drop	Facial burns have been reported with earlier versions.
No affect due to changes in water vapor pressure	Sensor windows may clog with secretions.
No deformity of capnograms due to non dispersion of gases	Difficult to use in unusual patient positioning such as in prone positions .
No delay in recording	



waveforms which reflect real-time $ETCO_2$ in the patient airway.

Side-Steam Capnographs

In sidestream technology, the respiratory gases are aspirated *via* an adaptor and a 6-foot sampling tube to the monitor housing the infrared sensor. The transport of gases to the infrared measuring device results in a delay of 1–4 s in carbon dioxide measurement and display of capnograms in sidestream capnography.

By connecting the sensor to a mask or nasal prongs or an ET tube $ETCO_2$ can be measured in the intubated or unintubated patient.

Side-stream Capnographs	
Advantages	**Disadvantages**
Easy to connect	Delay in recording due to movement of gases from the ET to the unit
No problems with sterilization	Sampling tube obstruction
Can be used in awake patients	Water vapor pressure changes affect CO_2 concentrations
Easy to use when patient is in unusual positions such as in prone position	Pressure drop along the sampling tube affects CO_2 measurements
Can be used in collaboration with simultaneous oxygen administration via a nasal prong	Deformity of capnograms in children due to dispersion of gases in sampling tubes

Main-Stream Capnographs

In the mainstream capnograph, a sample cell or cuvette (airway adapter) is inserted directly in the airway between the breathing circuit and the endotracheal tube. A lightweight infrared sensor is then attached to the airway adapter. The sensor emits infrared light through the adapter windows to a photodetector typically located on the other side of the airway adapter. CO_2 absorbs Infra red light at 4.3 µm. The light which reaches the photodetector is used to measure $ETCO_2$. Mainstream technology eliminates the need for gas sampling and scavenging as the measurement is made directly in the airway. This sampling technique results in crisper

Clinical information can be obtained from three sources in capnography: numerical value of $PETCO_2$, shape of the capnograms, and the difference between $PETCO_2$ and $PaCO_2$. The shapes of the capnograms offer more specific diagnostic clues. It is difficult to use capnography as a diagnostic tool by itself. However, if the changes in $PETCO_2$ values or variations in the carbon dioxide waveforms are used in conjunction with accompanying data, such as heart rate, blood pressure, respiratory flow, pulmonary inflation pressures, and minute volumes, the diagnostic accuracy of capnography can be enhanced.[4]

For accurate measurements capnographs must be calibrated periodically, at different intervals in various models as per the manufacturers' guidelines, but at least daily.[5]

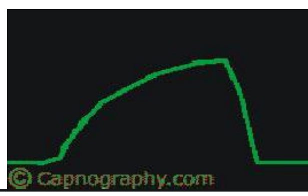
Interpretation of Capnogram

Capnography in Emergency Tracheal Intubations

Air Leak

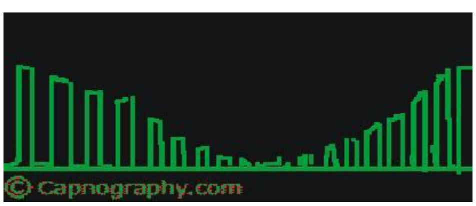
Loose connection between sampling tubeand capnograph

Bronchospasm/ET Tube Obstruction



Slanting and prolonged phase 2 and increased slope of phase 3

Trend during Cardiac Arrest & Resuscitation

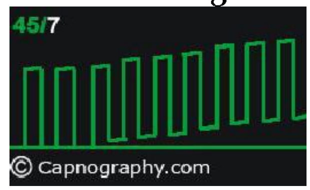


Return of Spontaneous Circulation generated by Chest compression

Esophageal Intubation

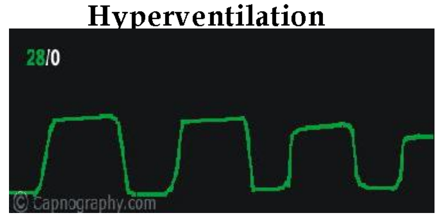
Absent wave form & Co2 peak

Rebreathing



Gradual elevation of base line and $ETCO_2$ values.

Hyperventilation

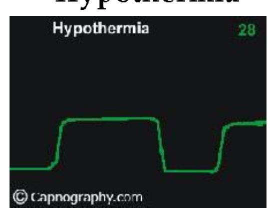


Gradual lowering of $ETCO_2$ values.

Hypoventilation

Gradual increase in CO_2 values from normal base line.

Hypothermia



Gradual decrease in CO2 values due to reduced metabolism

Majority of emergency intubations are performed in surroundings that are less than ideal circumstances as compared to those in operating rooms. Therefore all tracheal intubations should be confirmed for endotracheal placement. Esophageal intubation or misplaced endotracheal tube can result in unsuccessful resuscitation, or can result in worsening of cardio respiratory status.

Until recently, calorimetric devices are the only portable devices suited for this purpose. The p^H sensitive indicator changes color when exposed to CO_2. Now we have realized the full benefits of capnography for confirming endotracheal intubations.

Capnography in Cardiopulmonary Resuscitation

During resuscitation, exhaled CO_2 is a better guide to the presence of circulation than an electrocardiogram, pulse or blood pressure.The revised guidelines of Advanced Cardiac Life Support (ACLS) 2010 recommend the use of quantitative waveform capnography not only for confirmation of tracheal tube placement but also to monitor the effectiveness of chest compressions. For given ventilation in acute settings, $PETCO_2$ serves an indirect monitor of cardiac output generated by chest compressions. The return of spontaneous circulation(ROSC) is sometimes difficult to assess with other methods, but it is clearly demonstrated on the capnography measurements by an abrupt increase in the $PETCO_2$ value. Continuous waveform capnography also provides immediate detection of tube displacement, much earlier than pulse oximetry.[6]

Capnography for Procedural Sedation

The American Society of Anesthesiologists (ASA) and the Association of Anaesthetists of Great Britain and Ireland (AAGBI) have issued revised standards in 2011 to monitor ventilation by capnography to enhance safety of patients undergoing sedation, irrespective of the location of procedural sedation.[7,8]

Transportation of Patients on Ventilator Within and Outside the Institution

Monitoring carbon dioxide waveforms during transport assures the integrity of airway and ventilation. In one study, six of nine mishaps during interhospital or intrahospital transfers were detected by pulse oximetry and

Monitoring of $PETCO_2$ Using Mainstream Capnograph

capnography.[9]

Future of Capnography

Physicians from other specialties are becoming more aware of the value of capnography in enhancing patient safety. They are actively exploring other ancillary uses and advantages of capnography monitoring such as determining the prognostic role of $PETCO_2$ values at rest and during exercise in patients with heart failure to predict major cardiac events.[10] Using a convenience sample of children, researchers in Rhode Island demonstrated that nasal capnography was useful as a non-invasive screening tool for identifying children with diabetic ketoacidosis (DKA).[11] In an evaluation of young children (mean age 4 years) who presented to the emergency department with symptoms consistent with gastroenteritis, $ETCO_2$ measurement highly correlates with serum bicarbonate levels suggesting that capnography could be used as a non-invasive measure of acidosis.[12] The applications and interpretations of capnography in children have been classified into six categories—Anesthetic Delivery Apparatus, Airway, Breathing, Circulation, Homeostasis and Non-perioperative in a review article from Canada[13]. It is found to be the earliest indicator of respiratory distress and helpful in rapid identification of upper airway obstruction[14].

Limitations of Capnography

Changes in alveolar ventilation can affect results. In patients with altered ventilation/ perfusion ratios (chronic obstructive pulmonary disease, atelectasis, chronic congestive heart failure, respiratory distress syndrome) the difference between pet CO_2 and arterial pCO_2 may increase up to 20 mmHg or more because of a decrease in pet CO_2 stemming from non -perfused areas. In addition pet CO_2 is typically decreased after administration of vasopressor drugs (an increase of the veno-arterial mismatch, whereby CO_2 returns to the arterial circuit after shunting the alveoli).[15]

Key Points

1. Capnography should be used for all intubations in the emergency department(ED).
2. Capnography should be used for intubated patients during transfers from the ED to other departments.
3. Training of all clinical staff who work in the emergency and ICU should include interpretation of capnography. Teaching should focus on identification of airway obstruction or displacement. In addition, recognition of the abnormal (but not flat) capnograph trace during CPR should be emphasized.

References

1. Badal JJ, Loeb RG, Trujillo DK. A simple method to determine mixed exhaled CO2 using a standard cycle breathing circuit. *Anesth Analg.* 2007; 105: 1048-52.
2. Kodali, Bhavani Shankar M.D. Capnography Outside the Operating Rooms. *Anesthesiology: Anesthesiology.* 2013; 118(1): 192-201.
3. Hagerty JJ, Kleinman ME, Zurakowski D, Lyons AC, Krauss B. Accuracy of a new low-flow sidestream capnography technology in newborns: A pilot study. *J Perinatol.* 2002; 22: 219–25.
4. Bhavani-Shankar K, Kumar AY, Moseley HS, Ahyee-Hallsworth R. Terminology and the current limitations of time capnography: A brief review. *J Clin Monit.* 1995; 11: 175–82.
5. Dr. Jacqueline d'mello, butani. Capnography. *Indian J Anaesth.* 2002; 46(4): 269-278.
6. Falk JL, Rackow EC, Weil MH. End-tidal carbon dioxide concentration during cardiopulmonary resuscitation. *N Engl J Med.* 1988; 318: 607–11.
7. Sacchetti A, Senula G, Strickland J, Dubin R. Procedural sedation in the community emergency department: Initial results of the Pro SCED registry. *Acad Emerg Med.* 2007; 14: 41–6.
8. Jonathan B Waugh PhD, Chad A Epps MD, Yulia A Khodneva MD, PhD. Cochrane review. Capnography enhances surveillance of respiratory eventsduring procedural sedation: a meta-analysis. *Journal of Clinical Anesthesia.* 2011; 23: 189-196.
9. Rückoldt H, Marx G, Leuwer M, Panning B, Piepenbrock S. Pulse oximetry and capnography in intensive care transportation: Combined use reduces transportation risks. *Anasthesiol Intensivmed Notfallmed Schmerzther.* 1998; 33: 32–6.
10. Arena R, Guazzi M, Myers J, Chase P, Bensimhon D, Cahalin LP, Peberdy MA, Ashley E, West E, Forman DE. The prognostic utility of cardiopulmonary exercise testing stands the test of time in patients with heart failure. *J Cardiopulm Rehabil Prev.* 2012; 32: 198–202.
11. Fearon DM, & Steele DW. End-tidal carbon dioxide predicts the presence and severity of acidosis in children with diabetes. *Academic Emergency Medicine.* 2002; 9(12): 1373–1378.
12. Nagler J, Wright RO, & Krauss B. End-tidal carbon dioxide as a measure of acidosis among children with gastroenteritis. *Pediatrics.* 2006; 118(1): 260–267.
13. Eipe N, Doherty DR. A review of pediatric capnography. *J Clin Monit Comput.* 2010; 24(4):

261-8.

14. Krauss, Baruch, MD, EdM. Advances in the Use of Capnography for Nonintubated Patients. Advances in Nonintubated Capnography. *Israeli Journal of Emergency Medicine.* 2008; 8(3).

15. Stefek Grmec, Mirjam Golub, Alina Jelatancev, Signa Vitae. 2009; 4(1): 24-26.