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Editorial Open Access

Capnography in the Emergency Department

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Abbrevations: COPD: Chronic Obstructive Pulmonary Disease; $ETCO_2$: End Tidal CO_2; ETT: Endo Tracheal Tube; $PaCO_2$: Arterial Pressure of CO_2; AHA: American Heart Association; ROSC: Return of Spontaneous Circulation; CPR: Cardiopulmonary Resuscitation

"Laudation to the God of majesty and glory! Obedience to him is a cause of approach and gratitude in increase of benefits. Every inhalation of the breath prolongs life and every expiration of it gladdens our nature; wherefore every breath confers two benefits and for every breath gratitude is due."[1]

Saadi Shirazi, the prominent Persian-Iranian poet living in the 12th-13th century whose aphorism "Bani Adam" or the Children of Adam ornaments the entrance of the United Nations, in the introduction section of the Golestan, has elaborately described the importance of the two sections of respiration.

Capnography is one of the non-invasive methods used for the measurement of End-tidal CO_2 values ($ETCO_2$). Values for $ETCO_2$ alter based on the CO_2 concentrations in each respiratory cycle [1]. Ancient Greeks believed that human body is equipped with a kind of "combustion engine" producing smoke, i.e. breathing; hence, the termcapnography is derived from the Greek word "Capnos" meaning smoke [1,2].

The mechanism of respiration includes two stages of oxygenation and ventilation with are considered as the natural physiological functions of the body that should be taken into consideration in the evaluation of the intubated patients and non-intubated patients with normal respiration. Oxygenation can normally be monitored using pulse oxymetry whereas capnography can provide more accurate information on each respiration cycle regarding ventilation, perfusion, cardiac output, pulmonary blood flow and metabolic status [1].

Carbon dioxide is produced a human body following glucose metabolism which is later delivered to pulmonary blood circulation transferred to the exhaled air through the alveoli. In expiration phase, primarily the air in the upper airways is exhaled; the process is followed by the expiration of the air content of the lower airways. Capnogram demonstrates CO_2 content of the expired air throughout the whole expiration phase. Most technologies used in the capnography are based on infrared wave; as CO_2 absorbs infrared waves in the specific wavelength of 4.26 nm. Therefore, the amount of the absorbed waves is in close relation with the CO_2 content of the expired air [1-3].

In patients with normal pulmonary function, apart from their age, the difference between $ETCO_2$ and arterial carbon dioxide pressure ($PaCO_2$) is a constant figure (2-5 mmHg) [2,3]. This difference originates from the dead alveolar spaces in a normal lung which is ineffective in the ventilation process. Capnography device demonstrates $ETCO_2$ Values and its related curves [2]. A normal capnogram has been illustrated in figure 1 in which the blue line is indicative of $PaCO_2$. The distance between the blue line and section III (C-D distance) is the normal befriends between $ETCO_2$ and $PaCO_2$.

[1]*From The Golestan of Saadi, by Sheikh Mosleh al-Din Saadi Shirazi, Translated by Richard Francis Burton, 1821-1890 CE.*

In this figure, A is the start point of inspiration; D is the end point of expiration from which the new inspiration cycle starts. The height of the curve is related to $ETCO_2$ whereas its width is related to expiration time [1,3]. The changes in the shape of the curve could be suggestive of the underlying diseases and the alterations in the $ETCO_2$ values could be utilized for the assessment of the severity of the diseases and response to treatment [1]. An emergency medicine physician should be aware of abnormal curves caused by technical problems of the device and also the contributing physiological and pathological conditions in order to monitor the patients more accurately and to increase his or her diagnostic abilities.

Indications for capnography in the emergency department:

1. Confirmation of the proper placement of the endotracheal tubes: in patients without cardiac arrest, capnography is of a 100% sensitivity and specificity for the confirmation of the proper placement of the endotracheal tubes [4-6].
2. Diagnosis of acidosis: in patients with acidosis, metabolic acidosis is compensated by hyperventilation leading to decrease in $PaCO_2$ and consequently in $ETCO_2$. In similar cases, e.g. ketoacidosis and renal failure, capnography could be used for the diagnosis of acidosis without using ABG. In many studies carried out on children with specious diabetic ketoacidosis, $ETCO_2$ values less than 29 mmHg has been associated with sensitivity 83% and specificity of 100% [7,8].

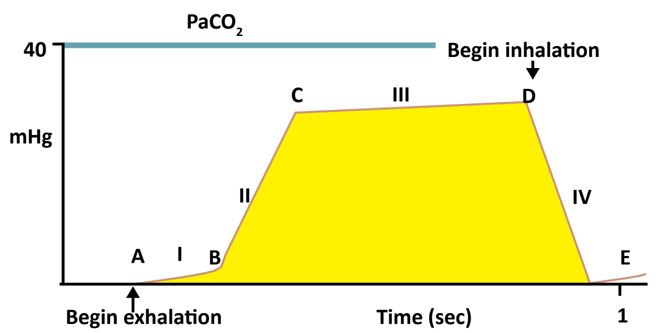

Figure 1: Normal capnography.

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3. Throughout CPR: according to the guidelines of the CPR published by AHA 2010, capnography is a compulsory monitoring throughout the resuscitation of the patients [9].
4. $ETCO_2$ more than 10 mmHg has been recommended for a successful resuscitation and any dramatic increase in capnography throughout CPR could be considered as an early indicative of ROSC. As capnography is in close relation with cardiac output and a minimum of 30% of the normal cardiac output is required to maintain the activity of vital organs including the heart and brain, $ETCO_2$ should be about 30% or 10-15 mmHg in each chest compression [9]. This is of great importance in emergency situations and natural disasters (earth quake, flood and etc.) in which physicians are overwhelmed by the magnitude of the event and the number of the ones in need of medical care [10].
5. Procedural sedation: In procedural sedation, capnography is a required monitoring device (especially in the procedures requiring moderate to deep sedation) as it is able to reveal the ventilation problems prior to any alterations in the clinical status of the patients [3,11].

Considering the different associated patterns of the capnography curves, the findings of their related pathologies are as follows (Figure 2) [12,13]:

1. Rebreathing: In this pattern, the descending part of the curve (phase IV) does not reach the zero line. The common causes would include low pressure oxygen stream into the mask or problem in the valve section of the non-breather mask.
2. Bronchoconstriction: In this condition, the slope of the ascending section of the curve (phase II) decreases resembling shark fin. This pattern is mostly seen in asthma or COPD patients.

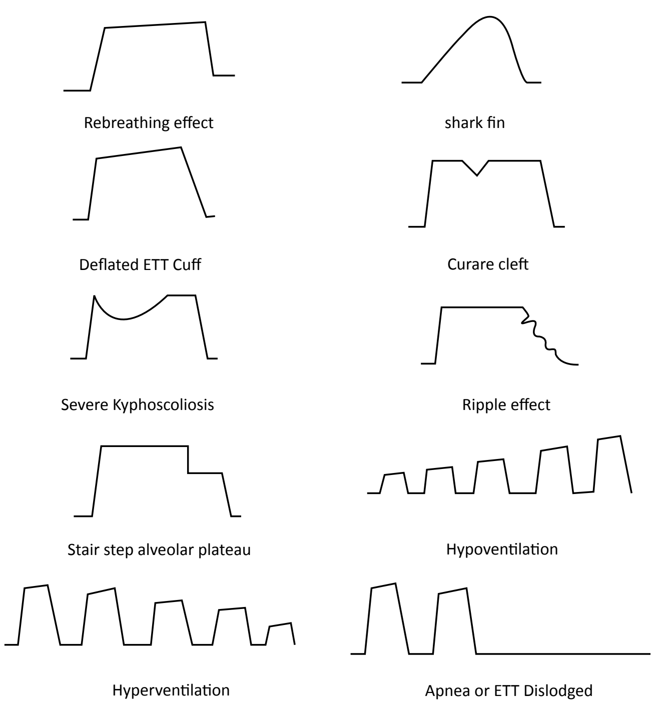

Figure 2: Different capnography patterns.

3. Prolonged phase IV: In intubated patients, whenever the cuff is deflated or a smaller size tube has been selected (especially in children), air leakage would occur causing this pattern.
4. Curare cleft: In intubated patients under mechanical ventilation, when the effect of the muscle relaxants wears off, this pattern emerges due to the return of the diaphragm constrictions indicating the requirement for further muscle relaxation.
5. Severe kyphoscoliosis: A bi-phasic pattern could be observed in the plateau section (phase III) of the curve.
6. Ripple effect: This effect, Cardiogenic Oscillations, is a normal variant mostly seen while inspiration due to the expansion of the lungs and their contact with the heart throughout the phase IV of the curve.
7. Stair step alveolar plateau: In this pattern, the ending half of the alveolar or III phase resembles stairs or steps, especially in intubated patients under mechanical ventilation whenever the oxygen pressure decreases in the ventilator.
8. Hypoventilation: The range of the curve increase due to the increased arterial CO_2 content.
9. Hyperventilation: The range of the curve decrease due to the decreased arterial CO_2 content caused by increased minute ventilation.
10. Apnea or dislodged ETT: No curve could be detected in the monitor.
11. Pneumothorax: In patients with tension pneumothorax, due to decrease in cardiac output caused by the pressure effect of the pneumothorax on the heart, $ETCO_2$ values decrease leading to a decreased range of the curve. In patients with small non-tension pneumothorax, if under mechanical ventilation and in volume modes, intra-pulmonary pressure increases and cardiac output decreases as in each inspiration a constant volume enters the lungs; consequently, the $ETCO_2$ values decrease. However, on the other hand in the pressure modes, smaller volumes enter the lungs due to the existing pneumothorax leading to a hypoventilation state associated with increased $ETCO_2$ values.

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