Capnography for the Radiology and Imaging Nurse: A Primer CE

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ABSTRACT: **Capnography monitoring was introduced into practice within the United States in the late 1970s and has received limited clinical adoption into radiology nursing practice, despite the growing level of evidence that supports patient safety and clinical care. Barriers for adoption of capnography monitoring may be financial, used as a surrogate for oxygenation, may lack a standardized analysis method, and may have limited clinician familiarity in preventing spurious interpretations. This article will provide concepts for capnography monitoring, practical uses, physiology overview, and a standardized method for analysis. In addition, it will offer a basic overview of airway management from the unique perspective of a nurse providing moderate sedation in radiology and imaging settings. (J Radiol Nurs 2016;35:173-190.)**

KEYWORDS: **Capnography; Monitoring; $PetCO_2$; $EtCO_2$; End-tidal monitoring; Carbon dioxide monitoring; Patient safety.**

INTRODUCTION

The history of capnography is rich and relatively unknown by health care professionals using this technology. Kapnós is the Greek root word that denotes smoke or vapor (Lexilogos, 2016). A root word so closely related to ventilation can be somewhat misleading for the full spectrum of utility that monitoring of exhaled carbon dioxide (CO_2) provides. A broad range of practical applications exist for the measurement of CO_2 that go beyond the measure of ventilation. The measurement of exhaled CO_2 is the only direct physiologic parameter readily available that is noninvasive. This article will limit its focus to concepts pertinent to time capnography. Time capnography devices are able to monitor expiratory and inspiratory phases of respiration, are the most commonly available capnography devices in practice, but have limited ability to estimate a patient's physiologic dead space (Bhalla et al., 2015; Suarez-Sipman, Bohm, & Tusman, 2014).

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HISTORY

The presence of evil air was known during the Roman times (27 BC–393 AD) when dogs would be overcomed after entering the *Grotta del Cane* in Naples (Westhorpe & Ball, 2010). Humans who were standing upright were unaffected by the vented volcanic CO_2

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gas, which was heavier than the air seeping up from the floor of the cave (Almqvist, 2003). Later in the middle 1600s, Dutch physician and scientist, Johann Baptist van Helmont first identified that there was a gas produced with fermentation and after the burring of wood. Dr. van Helmont wrote, “In consequence of burning coal *Spiritus Sylvestris* comes into being. This *spiritus*, which was formally unknown and cannot be kept in vessels, and cannot be converted into visible form, I call by the new name – gas” (Almqvist, 2003). Joseph Black, a consummate professor, scientist, and physician, discovered CO_2 in the mid-1750s referencing it as fixed air (Simpson, 1982). Dr. Black was able to demonstrate in his experiments that fixed air remained after burning magnesium carbonate, was heavier than common air, could extinguish a flame, and would suffocate animals (Simpson, 1982). By the early 1900s, CO_2 monitoring was being performed on World War I submarines to prevent acute intoxication from exposure to the submarine atmosphere (Knight, Tappen, Bowman, O’Neil, & Gordon, 1988). One of the limitations for submarines underwater was the effect of human metabolism that increased ambient CO_2 levels and decreased the percentage of available oxygen (Knight et al., 1988). To prevent acute intoxication, submarines would be required to surface and revitalize the ambient air (Knight et al., 1988).

Dr. John Haldane, considered the father of oxygen therapy, described the first practical use of a CO_2 analyzer in the early 20th century, which led to the discovery that respiratory reflexes were triggered by an excess of CO_2 and not the lack of oxygen (Gravenstein, Jaffe, & Paulus, 2005; Sekhar & Rao, 2014). Since this discovery, the use of capnography has slowly grown in popularity. In 1978, it was introduced in the United States at the World Congress of Intensive Care Medicine with a lackluster reception from the panel of anesthesiologists (Gravenstein et al., 2005). Ultimately, Holland was the first country to adopt capnography as a standard of monitoring during anesthesia. It was not until 2010 that the American Society of Anesthesiologists (2012) made it a standard for moderate or deep sedation practice for anesthesia providers.

DEFINITIONS

Capnography is the noninvasive measurement of exhaled concentration or partial pressure of CO_2 ($PaCO_2$) with a continuous waveform. The capnogram is the graphic representation of exhaled CO_2. Alternatively, there is capnometry, which is a monitoring device that measures the concentration of exhaled CO_2 and provides only a numerical reading without a waveform. A cost-effective and disposable alternative to both devices mentioned previously is a colorimetric capnometer. These devices provide a semiquantitative reading that uses a pH-sensitive indicator that detects the presence of exhaled CO_2. End-tidal carbon dioxide ($ETCO_2$/$EtCO_2$) is the maximal concentration of CO_2 at the end of an exhaled breath that can be expressed as a percentage (5% to 6%) or in millimeter of mercury (35 to 45 mm Hg). A more precise abbreviation for partial pressure of expired CO_2 is $PetCO_2$. It is not uncommon for end tidal to be used as a vernacular for capnography or capnometry. $PetCO_2$ will be used in this article to express capnography as a partial pressure measurement and a waveform of expired CO_2.

OVERVIEW OF PHYSIOLOGY

Aerobic Metabolism

Physiologically, the process starts with the inhalation and intake of oxygen-rich air into the lungs. Oxygen crosses from the alveolar-capillary membrane into systemic circulation in the process of diffusion. The oxygenated blood is carried to the tissues after attaching to hemoglobin, where it will be used by the mitochondrion (Budd & McCance, 1990). In order for cellular respiration to be carried out efficiently via normal pathways, glucose must be available to support aerobic metabolism. During aerobic metabolism, CO_2 is produced and transported back to capillary circulation of the lungs for diffusion of CO_2 back into the alveoli to be exhaled (Budd & McCance, 1990). The regulation of ventilation occurs not only in the central nervous system but also is influenced by chemoreceptors (central—brainstem and peripheral—aortic arch/carotid bodies) and mechanoreceptors in the lungs (Budd & McCance, 1990). On the end of the respiratory cycle, the patient produces a capnographic waveform as a result of the measurement of CO_2 (Table 1). The capnographic waveform is evaluated methodically with four phases to indicate the respiratory cycle. In addition, both alpha and beta angles are examined to reveal any sloping, notching, or prolong phases. Finally, in addition to the capnogram, trend, $PaCO_2$ to $PetCO_2$ gradient, physical examination, and history must be considered.

Ventilation/Perfusion

When an equal number of alveoli are ventilated and perfused, ventilation and perfusion are equally matched. If more alveoli are perfused, than ventilated, then the ventilation/perfusion (V/Q) mismatch is a pulmonary shunt. A pulmonary shunt is alveoli perfusion without ventilation (Budd & McCance, 1990). This type of V/Q mismatch results from pulmonary pathologies that prevent gas exchange by diffusion on the alveoli side of the alveolar-capillary membrane. The