AARC Clinical Practice Guideline

Capnography/Capnometry during Mechanical Ventilation—2003 Revision & Update

CO2 MV 1.0 PROCEDURE:
Capnography comprises the continuous analysis and recording of carbon dioxide concentrations [CO_2] in respiratory gases. Although the terms capnography and capnometry are sometimes considered synonymous, capnometry suggests measurement (ie, analysis alone) without a continuous written record or waveform. Capnographic waveforms may be time-based or volume-based.

CO2 MV 2.0 DESCRIPTION/DEFINITION:
For the purposes of this Guideline, capnography refers to the evaluation of the [CO_2] in the respiratory gases of mechanically ventilated patients. A capnographic device incorporates one of two types of analyzers: mainstream or sidestream.[1,2] Mainstream analyzers insert a sampling window into the ventilator circuit for measurement of CO_2, whereas a sidestream analyzer aspirates gas from the ventilator circuit, and the analysis occurs away from the ventilator circuit. Analyzers utilize infrared, mass or Raman spectra, or a photoacoustic spectra technology.[3-5] Flow measuring devices are utilized in volume-based capnographs.

CO2 MV 3.0 SETTING:
This procedure may be performed by trained health care personnel in any setting in which mechanically ventilated patients are found—for example, the hospital, the extended care facility, or during transport.

CO2 MV 4.0 INDICATIONS:
On the basis of available evidence, capnography should not be mandated for all patients receiving mechanical ventilatory support, but it may be indicated for:

4.1 Evaluation of the exhaled [CO_2], especially end-tidal CO_2, which is the maximum partial pressure of CO_2 exhaled during a tidal breath (just prior to the beginning of inspiration) and is designated P_{etCO_2}[6,7]

4.2 Monitoring severity of pulmonary disease[5] and evaluating response to therapy, especially therapy intended to improve the ratio of dead space to tidal volume ($\dot{V}_D/\dot{V}_T$)[8,9] and the matching of ventilation to perfusion ($\dot{V}/\dot{Q}$),[10] and, possibly, to increase coronary blood flow[6,11,12]

4.3 Use as an adjunct to determine that tracheal rather than esophageal intubation has taken place (Low or absent cardiac output may negate its use for this indication.);[13-18] colorimetric CO_2 detectors are adequate devices for this purpose.[19]

4.4 Continued monitoring of the integrity of the ventilatory circuit, including the artificial airway[13,16]

4.5 Evaluation of the efficiency of mechanical ventilatory support by determination of the difference between the arterial partial pressure for CO_2 (P_{aCO_2}) and the P_{etCO_2}[20,21]

4.6. Monitoring adequacy of pulmonary, systemic, and coronary blood flow[11,12,22-26]

4.6.1 Estimation of effective (nonshunted) pulmonary capillary blood flow by a partial rebreathing method[27-29]

4.6.2 Use as an adjunctive tool to screen for pulmonary embolism (Evidence for the utility of dead space determinations as a screening tool for pulmonary embolism is at present not conclusive.)[30,31]

4.6.3 Monitoring the matching of ventilation to perfusion during independent lung ventilation for unilateral pulmonary contusion[32]

4.7 Monitoring inspired CO_2 when CO_2 gas is being therapeutically administered[33]

4.8 Graphic evaluation of the ventilator-patient interface; evaluation of the shape of the capnogram may be useful in detecting rebreathing of CO_2, obstructive pulmonary disease, waning

neuromuscular blockade ('curare cleft'), cardiogenic oscillations, esophageal intubation, cardiac arrest, and contamination of the monitor or sampling line with secretions or mucus.[6,34]

4.9 Measurement of the volume of CO_2 elimination to assess metabolic rate and/or alveolar ventilation[35]

CO2 MV 5.0 CONTRAINDICATIONS:

There are no absolute contraindications to capnography in mechanically ventilated patients provided that the data obtained are evaluated with consideration given to the patient's clinical condition.

CO2 MV 6.0 HAZARDS/COMPLICATIONS:

Capnography with a clinically approved device is a safe, noninvasive test, associated with few hazards. With mainstream analyzers, the use of too large a sampling window may introduce an excessive amount of dead space into the ventilator circuit.[2,36] Care must be taken to minimize the amount of additional weight placed on the artificial airway by the addition of the sampling window or, in the case of a sidestream analyzer, the sampling line.

CO2 MV 7.0 LIMITATIONS OF PROCEDURE OR DEVICE:

Capnography, when performed using a device calibrated and operated as recommended by the manufacturer, has few limitations. It is important to note that although the capnograph provides valuable information about the efficiency of ventilation (as well as pulmonary, systemic, and coronary perfusion), it is not a replacement or substitute for assessing the P_{aCO_2}.[20,34,37-41] The difference between P_{etCO_2} and P_{aCO_2} increases as dead-space volume increases. In fact, the difference between the P_{aCO_2} and P_{etCO_2} has been shown to vary within the same patient over time.[42-47] Alterations in breathing pattern and tidal volume may introduce error into measurements designed to be made during stable, steady-state conditions.[48-50] Interpretation of results must take into account the stability of physiologic parameters such as minute ventilation, tidal volume, cardiac output, ventilation/perfusion ratios and CO_2 body stores.[51,52] Certain situations may affect the reliability of the capnogram. The extent to which the reliability is affected varies somewhat among types of devices (infrared,[53] photoacoustic, mass spectrometry, and Raman spectrometry). Limitations include:

7.1 The composition of the respiratory gas mixture may affect the capnogram (depending on the measurement technology incorporated).

7.1.1 The infrared spectrum of CO_2 has some similarities to the spectra for both oxygen and nitrous oxide.[53] High concentrations of either or both oxygen or nitrous oxide may affect the capnogram, and, therefore, a correction factor should be incorporated into the calibration of any capnograph used in such a setting.[54]

7.1.2 The reporting algorithm of some devices (primarily mass spectrometers) assumes that the only gases present in the sample are those that the device is capable of measuring.[55] When a gas that the mass spectrometer cannot detect (such as helium) is present, the reported values of CO_2 are incorrectly elevated in proportion to the concentration of helium present.

7.2 The breathing frequency may affect the capnograph. High breathing frequencies may exceed the response capabilities of the capnograph.[56] In addition, breathing frequency above 10 breaths/min has been shown to affect devices differently.[57]

7.3 The presence of Freon (used as a propellant in metered dose inhalers) in the respiratory gas has been shown to artificially increase the CO_2 reading of mass spectrometers (ie, to show an apparent increase in $[CO_2]$). A similar effect has not yet been demonstrated with Raman or infrared spectrometers.[58]

7.4 Contamination of the monitor or sampling system by secretions or condensate, a sample tube of excessive length, a sampling rate that is too high, or obstruction of the sampling chamber can lead to unreliable results.

7.5 Use of filters between the patient airway and the sampling line of the capnograph may lead to lowered P_{etCO_2} readings.[59,60]

7.6 Low cardiac output may cause a false negative result when attempting to verify endotracheal tube (ETT) position in the trachea. False positive results have been reported with ETT position in the pharynx and when antacids

and/or carbonated beverages are present in the stomach.[18,61]

7.7 Decreased tidal volume delivery is possible during volume modes, some dual control modes, and time-cycled pressure limited ventilation with low continuous flowrates if the sampling flowrate of a sidestream analyzer is too high, especially in neonates and pediatrics.

7.8 Inaccurate measurement of expired CO_2 may be caused by leaks of gas from the patient/ventilator system preventing collection of expired gases, including

7.8.1 Leaks in the ventilator circuit[62]

7.8.2 Leaks around tracheal tube cuffs or uncuffed tubes[62]

CO2 MV 8.0 ASSESSMENT OF NEED:

Capnography is considered a standard of care during anesthesia.[13,63] The American Society of Anesthesiologists has suggested that capnography be available for patients with acute ventilatory failure on mechanical ventilatory support.[63] The American College of Emergency Physicians recommends capnography as an adjunctive method to ensure proper ETT position.[64] The international guidelines for emergency cardiovascular care recommend use of capnography to verify ETT placement in all age groups.[65] Assessment of the need to use capnography with a specific patient should be guided by the clinical situation. The patient's primary cause of respiratory failure and the acuteness of his or her condition should be considered.

CO2 MV 9.0 ASSESSMENT OF OUTCOME:

Results should reflect the patient's condition and should validate the basis for ordering the monitoring. Documentation of results (along with all ventilatory and hemodynamic variables available), therapeutic interventions, and/or clinical decisions made based on the capnogram should be included in the patient's chart.

CO2 MV 10.0 RESOURCES:

10.1 Equipment: The capnograph and accessories (eg, airway adapter, sampling tube, depending on capnograph). The capnograph should be calibrated as recommended by the manufacturer.

10.2 Personnel: Licensed or credentialed respiratory care practitioners or individuals with similar credentials (eg, MD, RN) who have the necessary training and demonstrated skills to correctly calibrate and evaluate the capnograph, assess the patient and the patient-ventilator system, and the ability to exercise appropriate clinical judgment.

CO2 MV 11.0 MONITORING:

During capnography the following should be considered and monitored:

11.1 Ventilatory variables: tidal volume, respiratory rate, positive end-expiratory pressure, inspiratory-to-expiratory time ratio (I:E), peak airway pressure, and concentrations of respiratory gas mixture[36,37]

11.2 Hemodynamic variables: systemic and pulmonary blood pressures, cardiac output, shunt, and ventilation-perfusion imbalances[36,37]

CO2 MV 12.0 FREQUENCY:

Capnography (or, at least, capnometry) should be available during endotracheal intubation.[13,14,16,37,64] Capnography is not indicated for every mechanically ventilated patient; however, when it is used, the measurement period should be long enough to allow determination of the P_{aCO_2}-P_{etCO_2} difference, note changes in P_{aCO_2}-P_{etCO_2} difference as a result of therapy, and allow interpretation of observed trends.

CO2 MV 13.0 INFECTION CONTROL:

No specific precautions are necessary although Standard Precautions (as described by the Centers for Disease Control & Prevention)[66] and precautions designed to limit the spread of tuberculosis[67] should always be implemented during patient care.

13.1 The sensor (the portion of the device contacting the patient's airway) should be subjected to high-level disinfection between patients, according to the manufacturer's recommendations.

13.2 The monitor (the portion not contacting the patient or the patient's airway) should be cleaned as needed according to manufacturer's recommendations.

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Original Publication: Respir Care 1995;40(12):1321-1324.

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