A QUICK **REFERENCE GUIDE**

CO_2 Monitoring

Medtronic
Further, Together

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WHY
MEASURE CO_2?

Studies have shown that capnography can effectively detect adverse respiratory events — helping avoid life-threatening conditions and potentially irreversible patient injury. Capnography provides instantaneous feedback during placement of the endotracheal tube used for mechanical ventilation. It can help verify that the tube is correctly positioned to deliver gas to the lungs and that it remains in place throughout any manipulation of the patient. As the most rapid indicator of missed intubations, kinked sampling lines, or accidental extubation, capnography helps ensure reliable patient safety.

CO_2 monitoring has become a global standard of care for patient safety.[1,2] The American Society of Anesthesiologists, the American Association for Respiratory Care, and the American Hospital Association have all adopted standards and guidelines for CO_2 monitoring. The American Society of Anesthesiologists Standards for Basic Anesthetic Monitoring, updated in 2010, states that the adequacy of ventilation during both general anesthesia and moderate and deep sedation shall be continually evaluated by both "qualitative clinical signs" and monitoring of expired carbon dioxide.[1] This safety improvement identifies the monitoring of expired carbon dioxide as a means to assess ventilation adequacy and has been implemented in part due to the risks of procedural sedation.[2]

The 2010 update of the American Heart Association's guidelines for adult advanced cardiovascular life support included a number of important changes to the 2005 guidelines. In addition to changes to the cardiac arrest algorithms and drugs for therapies, this update includes recommendations for "continuous quantitative waveform capnography… for confirmation and monitoring of endotracheal tube placement." It also includes a discussion of the potential value of end-tidal CO_2 ($ETCO_2$) as an indicator of the return of spontaneous circulation and as a tool to optimize CPR quality.[3] Many states, such as Florida and New York, have laws mandating that every ambulance be equipped with a CO_2 measurement device. In Europe, some countries have adopted CO_2 monitoring as a result of societal standards and others as a result of individual country law.

Because of its benefits as a safety monitor and its ease of use, capnography technology is spreading much as pulse oximetry did. Miniaturization and technological advances also are fueling the increase in its use. Capnographs and capnometers today are small, very robust, and user friendly — allowing easy integration into patient monitors, defibrillators, and ventilators. Capnography is simple and inexpensive for the clinician.

THE MANY USES OF CAPNOGRAPHY

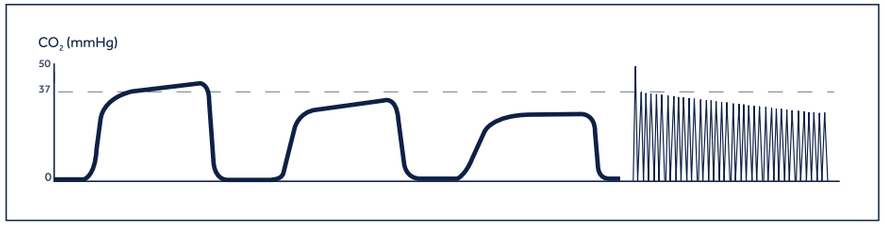
For ventilator management, capnography is used for:

- Determination of when to intubate or extubate
- Verification of endotracheal tube placement
- Alerts if accidental extubation occurs
- Ongoing airway management
- Initial setup, monitoring, and weaning from the ventilator
- Detection of ventilator disconnect
- Identification of hyper- and hypoventilation
- Determination of dead space (A-a CO_2 gradient)

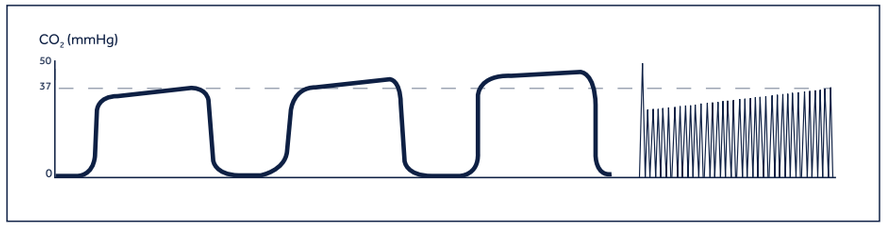
For monitoring and diagnosis, capnography is used for:

- Waveform analysis – breathing pattern assessment
- Visualization of changes in ventilatory pattern
- Assessment of patient/ventilator synchrony
- Monitoring for oversedation
- Verification of target $PaCO_2$ in head trauma patients
- Determination of loss of airway control
- Assessment of neuromuscular blockade drugs
- Evaluation of bronchodilator therapy
- Asthma management, especially in the ED
- Assessment of effectiveness of chest compressions during CPR
- Verification of ventilation during transport

Hyperventilation



Hypoventilation



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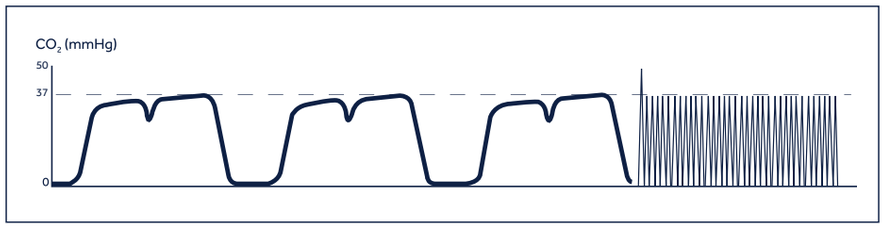
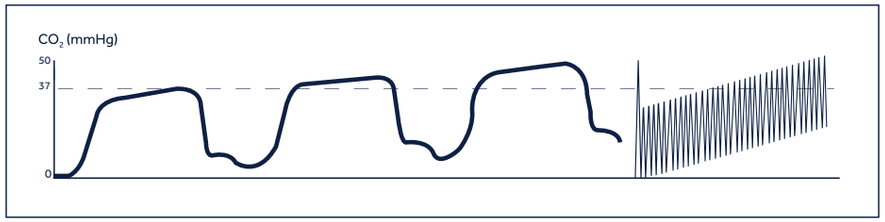
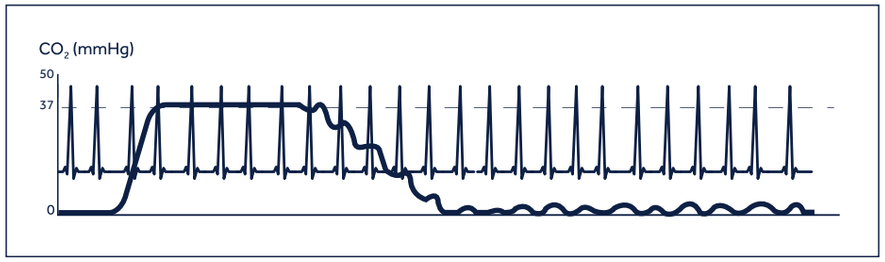


Faulty Exhalation Valve



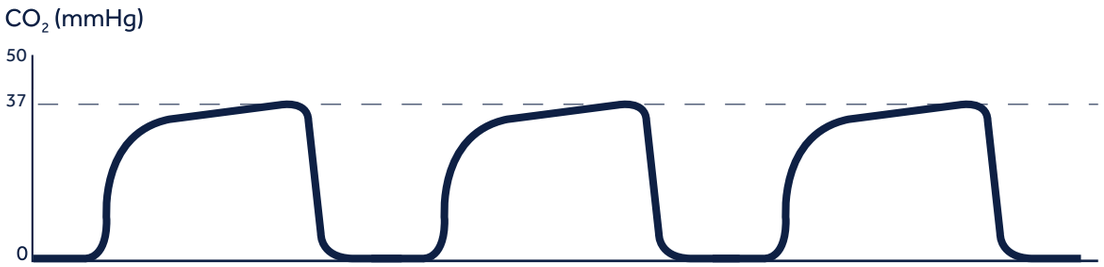
Cardiogenic Oscillations



MONITORING WITH MAINSTREAM VERSUS SIDESTREAM CO_2 SENSORS

Mainstream CO_2 Sensor

Sidestream CO_2 Sensor



Most appropriate form of $ETCO_2$ monitoring for mechanically ventilated intubated patients[4,5]	Used to monitor the $ETCO_2$ of nonintubated patients
On-airway measurement — immediate response	Sample diverted to measurement site from patient interface
CO_2 sensor located between the ET tube and the breathing circuit	Cannulas available that sample CO_2 and deliver O_2 simultaneously
Disposable and reusable adult/pediatric and infant/neonatal airway adapters	Cannulas can be placed on patients under masks, such as oxygen delivery or CPAP masks

ZEROING THE CO_2 SENSOR

An “adapter zero” is a quick procedure that adjusts the mainstream sensor to the optical characteristics of each compatible airway adapter. Follow these guidelines for performing an adapter zero.

For the mainstream CO_2 sensor:

- The procedure is necessary with the first use of the Capnostat™* CO_2 sensor.
- The procedure is necessary when switching the mainstream Capnostat™* sensor from one airway adapter type to another, such as from a disposable to a reusable airway adapter.
- Zeroing is not required when switching from the same type of airway adapter, such as from a disposable to a disposable airway adapter.
- The procedure is necessary when requested by the CO_2 monitor.
- Typical time for zero is 15 to 20 seconds.

Never zero the mainstream sensor without an adapter or sampling kit installed. When zeroing, always remove the adapter or cannula from the patient and keep all sources of CO_2 away from the sensor, including your own breath (CO_2 is heavier than air). Always refer to the user manual for complete instructions.

FREQUENTLY ASKED QUESTIONS **FOR CLINICIANS**

Q:

How is CO_2 measured using the mainstream sensor?

A:

The mainstream sensors measure the number of CO_2 particles in the exhaled gas using infrared light.

A broad band of light wavelengths is emitted by an infrared source. The light is then focused by a lens and transmitted across the airway adapter (mainstream sensor). CO_2 that passes through the light absorbs some of this light at a specific wavelength. The light is then focused through a filter set at the CO_2 absorption wavelength onto a detector. The amount of CO_2 in the airway is then determined by measuring the light that was absorbed.

Q:

When should I use the mainstream or the sidestream sensor?

A:

Knowing when or why to use the mainstream and sidestream sensors can seem confusing. Just consider that the end result is the same — monitoring $ETCO_2$.

Sidestream sensors are commonly used in emergency medicine and procedural sedation, and mainstream sensors are used for intubated patients.

Q:

Which is more accurate — the mainstream or the sidestream sensor?

A:

The accuracy specifications of mainstream CO_2 sensors and sidestream CO_2 sensors are the same.[6,7] The difference between the two sensors is the application and display of the capnogram. Sidestream sensors are typically used for nonintubated patients and mainstream sensors are used for intubated patients. The capnogram of the mainstream sensor is “crisper,” because sidestream sensor sampling tends to round the capnogram as the gas sample is drawn down the tubing to be measured.

FREQUENTLY ASKED QUESTIONS **FOR CLINICIANS (CONT'D.)**

Q:

What is the dead space of your adapters?

A:

Mainstream sensor adapters (SPU) :

- Pediatric/adult — approximately 6 cc of dead space
- Infant/neonatal — ≤1 cc of dead space

Q:

How do I determine which adapter to use?

A:

Use these guidelines to choose a mainstream adapter:

- Pediatric/adult — for use on ET tube sizes >4.0 mm
- Infant/neonatal — for use on ET tube sizes ≤4.0 mm

Q:

How should I position the CO_2 sensors?

A:

For the mainstream sensor, always keep the windows of the adapter in the vertical position. This will keep water and patient secretions from pooling on the windows.

FREQUENTLY ASKED QUESTIONS **FOR CLINICIANS (CONT'D.)**

Q:

What is the best method for dealing with breathing circuit humidity?

A:

The mainstream sensor is heated close to body temperature to keep the adapter warm, which prevents water vapor from condensing on the windows.

Q:

On which side of the heat/moisture exchange (HME) should I put the mainstream sensor airway adapter?

A:

The adapter can be placed on either side of the HME, but we recommend the following connections to keep the adapter dry:

- The HMe to the endotracheal tube adapter
- The mainstream sensor adapter to the HMe
- The breathing circuit to themainstream sensor adapter

Q:

What is a normal range for $ETCO_2$?

A:

The normal range for $ETCO_2$ is between 32 and 42 mm Hg, which is roughly 5% of CO_2. The mainstream sensor measures the patient's CO_2 from 1 to 150 mm Hg, or roughly 20% of CO_2. They both measure respiration rates up to 150 breaths per minute. The accuracy range is:

- 0 to 40 mm Hg ± 2 mm Hg
- 41 to 70 mm Hg ± 5% of reading
- 71 to 100 mm Hg ± 8% of reading
- 101 to 150 mm Hg ± 10% of reading

FREQUENTLY ASKED QUESTIONS **FOR CLINICIANS (CONT'D.)**

Q:

Does the sensor compensate for anesthetic agents and other gases?

A:

The user sets compensations in the host monitor for oxygen, helium, nitrous oxide, and anesthetic agents. Refer to the user manual for information on setting the compensations. Compensations are not needed for nitrogen or nitric oxide.

Q:

What is the barometric pressure used for and how do I set it?

A:

Barometric pressure is used to convert the numbers from pressure units of mm Hg or kPa to percentages. It is also used to correct for the effects of collision broadening in the gas sample — especially in high concentrations. Refer to the user manual for instructions on how to set barometric pressure. Typically, the mean barometric pressure for your area is set.

Q:

How quickly will I see the capnogram and numbers once I turn on the monitor?

A:

On startup and after the sensor warms up, perform the airway adapter zero. After connection to the patient, the mainstream sensor will display the capnogram within 15 seconds. The $ETCO_2$ and respiration rate will display within 30 seconds or less. Remember that if the sensor has been in a cold car all night it will take longer to complete the warmup. Always let the sensor warm up to room temperature before use.

FREQUENTLY ASKED QUESTIONS **FOR CLINICIANS (CONT'D.)**

Q:

What are the maintenance requirements for the CO_2 sensor?

A:

There is no required routine maintenance or required field calibration for the mainstream sensor. The mainstream sensors are calibrated at the factory and remain stable over time. The sensors store calibration information and continually validate the stored information. If an error is recognized, the sensor will send an error message.

Some biomeds set a yearly "maintenance check" of the sensors. The system is checked using a certified calibration gas.

Q:

What is a zero and when do I do this?

A:

A zero is performed whenever a mainstream sensor is connected to the monitor for the first time. Thereafter, perform a zero whenever a different style adapter is installed, such as when the system displays a message to perform a zero. It is not necessary to perform a zero when changing types within the same adapter style. For example, when changing from a neonatal single-patient use adapter to an adult single-patient use adapter, it is not necessary to perform a zero. Never zero the sensor without an adapter or sampling kit installed. When zeroing, always keep all sources of CO_2 away from the sensor, including your own breath. The zero only takes 15 to 20 seconds.

Q:

Is a zero a calibration?

A:

Not really. The function of a zero is to identify the optical characteristics (light transmission) of the adapter windows. The reusable adapter windows are sapphire and the single-patient use adapters are plastic. The sensor identifies the adapter by the adapter windows and this is done by performing a zero.

Q:

How can I get the regulator?

A:

Please check with your customer service department.

This guide is not intended to supplement or replace the instructions for use included with your medical device.

1. American Society of Anesthesiologists (ASA). Basic Standards for Intraoperative Monitoring; 1999.
2. Gravenstein JS, Jaffe MB, Paulus DA, eds. *Capnography: Clinical Aspects*. Cambridge, UK: Cambridge University Press; 2004.
3. ASA Standards for Basic Anesthetic Monitoring. Committee of Origin: Standards and Practice Parameters. (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010 with an effective date of July 1, 2011) . Accessed July 18, 2012.
4. Weinger MB, Lee LA. No patient shall be harmed by opioid-induced respiratory depression. *Anesthesia Patient Safety Foundation Newsletter*. 2011;26(2):21-40.
5. Jaffe MB. Mainstream or Sidestream Capnography? Wallingford, CT: Respironics Novametrix, Inc. 2012.
6. Capnostat Mainstream CO_2 Sensor. Respironics. 2010.
7. LoFlo Sidestream CO_2 Sensor. Respironics. 2010.

IMPORTANT: Please refer to the package insert for complete instructions, contraindications, warnings and precautions.

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