Cath Lab Digest

A product, news & clinical update for the cardiac catheterization laboratory specialist

CATH LAB SPOTLIGHT

The Heart Institute at Huntsville Hospital

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Tell us about your institution and cath lab.

Huntsville Hospital is a community-based, not-for-profit hospital that is part of a 13-hospital system and is a regional referral center. It is located in one of the fastest-growing metropolitan areas in Alabama, employing over 18,000 employees across northern Alabama. The 881 patient beds at the Huntsville Hospital main campus continue to maintain The Blue Cross Distinction Centers in Cardiac Care. In addition to being accredited by the Joint Commission, the hospital has received numerous recognitions for excellence in patient care for cardiac services.

Since our community is growing at a rapid pace, so must our cardiac service line.

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In This Issue

CASE REPORT

Making Complex Simple

Ori Waksman, MD; Hayder Hashim, MD, FSCAI

Revascularization of patients with unprotected left main disease poses a significant challenge due to the heightened risk of mortality and periprocedural hemodynamic collapse. Historically, such patients were managed surgically via coronary artery bypass grafting (CABG); however, randomized controlled trials (RCTs) demonstrating similar mortality and long-term outcomes with percutaneous coronary intervention (PCI) have shifted contemporary practice trends and broadened the use of unprotected left main percutaneous coronary intervention (ULM-PCI).

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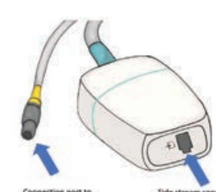
CATH LAB REVIEW

Waveform Capnography: Part of Comprehensive Vital Sign Monitoring

Richard J. Merschen, EdS, RT(R)(CV), RCIS; Madalynne Ruth, RT/ICVT student



Comprehensive vital sign monitoring is an essential patient safety requirement in the cath lab and includes invasive and non-invasive blood pressure, electrocardiogram (ECG), heart rate, and pulse oximetry. Another vital sign, used by anesthesia, respiratory therapy, and other care providers, is waveform capnography. Waveform capnography is a continuous, non-invasive measurement of a patient's ventilation effort and measures the amount of carbon dioxide (CO_2) in exhaled air.[1,2] It consists of two major elements: capnometry and waveform capnography.[1,2] Capnometry is the quantitative numerical value of CO_2 concentration, and focuses on end-tidal CO_2 ($ETCO_2$). $ETCO_2$ ranges from 35-45 mmHg, the same as CO_2 in a blood gas sample. Waveform capnography is a square-shaped graph measurement with slightly rounded corners that measures the entire respiratory cycle[2] (Figure 1). On the vertical axis of the capnography waveform, $ETCO_2$ is captured at the top right side of the square, which represents end expiration (Figure 1). Measuring the $ETCO_2$ on capnography is similar to measuring a hemodynamic pressure that has respiratory variance, with the measurement taken at the same point of end expiration (Figure 2).

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Waveform Capnography: Part of Comprehensive Vital Sign Monitoring

Richard J. Merschen, EdS, RT(R)(CV), RCIS; Madalynne Ruth, RT/ICVT student

Waveform capnography is useful because it provides earlier, more proactive information than pulse oximetry when assessing and monitoring the respiratory status of a patient.[1,2]

Capnography also measures time along the horizontal axis, which calculates the patient's respiratory rate. Waveform capnography is useful because it provides earlier, more proactive information than pulse oximetry when assessing and monitoring the respiratory status of a patient.[1,2] It is particularly valuable when measuring the respiratory status pf patients who are sedated and receiving oxygen.[1,2] Waveform capnography is also a critical tool for determining proper intubation, basic cardiac life support (BCLS) and advanced cardiac life support (ACLS) protocols, and the evaluation of the perfusion and metabolic states of patients. This overview will focus on the equipment used to capture waveform capnography, basic interpretation of the waveform, and its application in the cardiac cath lab.

Monitoring System

To perform capnography, a Sidestream or Mainstream measuring device is used. Mainstream devices are primarily used on intubated patients and directly measure $ETCO_2$ via a sensor on the hub of the endotracheal tube. Sidestream systems are commonly used in the cath lab and other procedural areas to measure $ETCO_2$ and can be used on patients receiving conscious sedation, monitored anesthesia care (MAC), or patients with advanced airways.[3,4] Sidestream systems have a sensor that measures CO_2 samples via a nasal cannula, nasal-oral cannula, or face mask. The sensor tubing is connected to an adapter that contains an infrared sensor and measures CO_2 samples throughout the respiratory cycle.[3] A commonly used sensor for this system involves a three-pronged cannula. The cannula has the usual nasal prongs, and a third, elongated prong between them. This prong sits over the mouth to take CO_2 samples (Figure 3), which are measured via infrared light.[3,4] Infrared light is absorbed by CO_2 at a specific wavelength and the sensor detects the infrared light using the exhaled breath from the patient. The capnography device then plots these measurements via an ongoing waveform.[3,4]

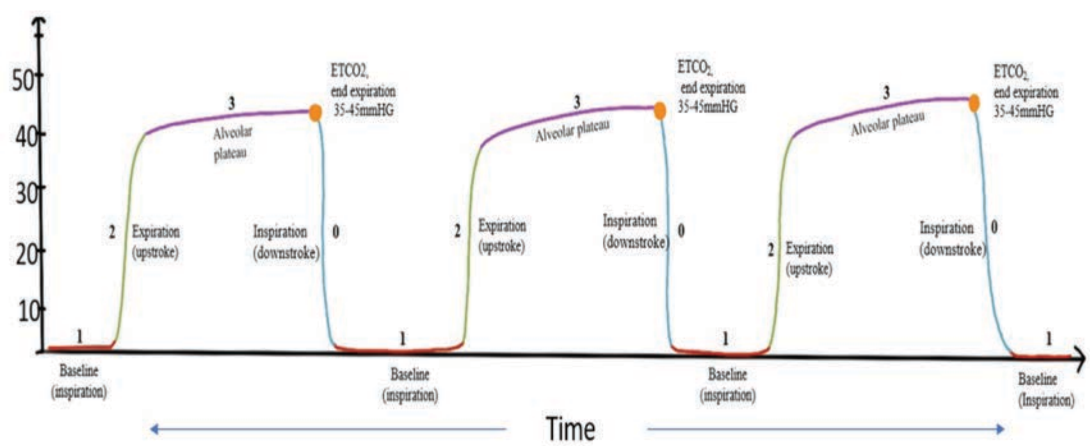

Figure 1. **A demonstration of the 4 phases of waveform capnography. Note a 50 mmHg scale for accurate measurement and the $ETCO_2$ measurement point at the end of phase 3.**

Figure 2. **(Left) $ETCO_2$ measurements on end expiration. (Right) The end expiration point for a pulmonary artery capillary wedge pressure. The right-hand image demonstrates the importance of the end expiration when measuring a patient's hemodynamic status.**

Waveform Capnography Interpretation

When interpreting waveform capnography, there are 4 distinct phases for each respiratory cycle (Figure 1). The phases are:[5-7]

Phase 1, which represents inhalation. This is the baseline measurement noted at the bottom of the waveform. There is no CO_2 is being eliminated when a patient is inhaling, with the baseline measurement around 0 mmHg.

Phase 2, which displays a rapid, steep upstroke on the capnography waveform as the patient begins to exhale. In phase 2, CO_2 begins to travel from the alveoli through the anatomical dead space of the airway, causing a rapid rise in the graph as the CO_2.[5-7]

In phase 3, there is an alveolar plateau, which comes to an endpoint. The plateau should have a consistent measurement between 35-45 mmHg. The end of the plateau represents $ETCO_2$ (35-45 mmHg), which is the most important measurement point for waveform capnography.

In phase 0, there is a rapid change from expiration to inhalation. There is a steep decline in the $ETCO_2$, because inhalation does not produce CO_2. The waveform returns to near zero at this point.

Waveform shape variations can indicate a wide variety of conditions such as asthma, poorly compliant lungs, displacement of an endotracheal tube, mechanical airway obstruction. Changes in the pressure indicate hypoventilation and hyperventilation (Figures 4 and 5).

3 PQRST Acronyms

When interpreting hemodynamics, PQRST is not just for ECGs. There are also three PQRST acronyms associated with waveform capnography interpretation. These acronyms interpret basic waveforms, proper intubation, and advanced airway management, and effective BCLS and ACLS care[5-10] (Table).

1) **For *basic monitoring*, PQRST determines the following:[7,8]**

Proper ventilation: Are the numbers and waveform characteristics normal? There should be normal ranges for CO_2 quantity and breathing rate. The waveform shapes should be normal and

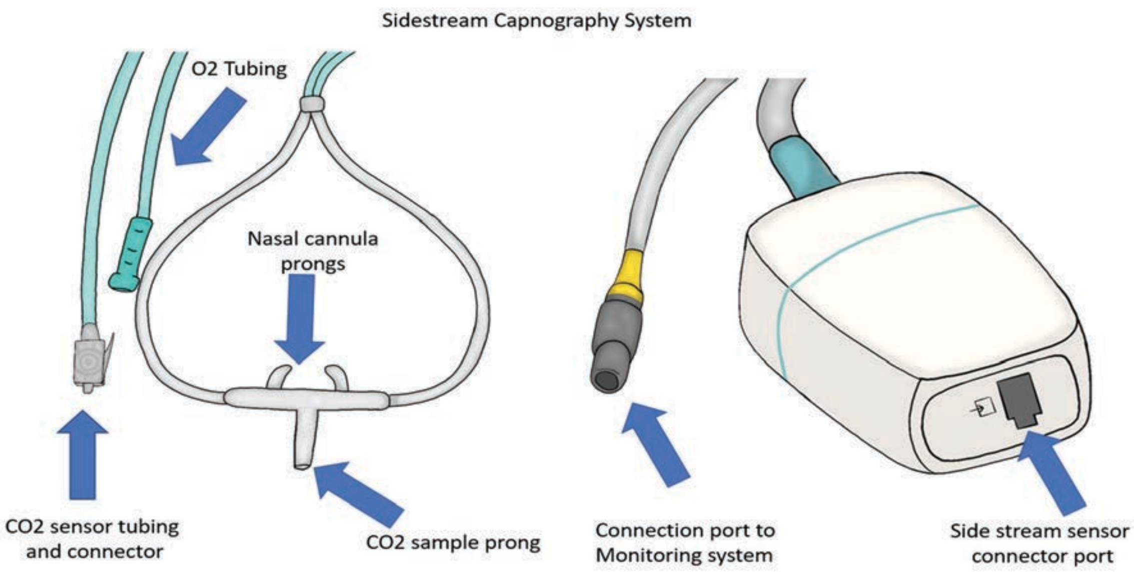

Figure 3. This image displays the key components of a sidestream waveform capnography system that can be used in a cardiac cath lab.

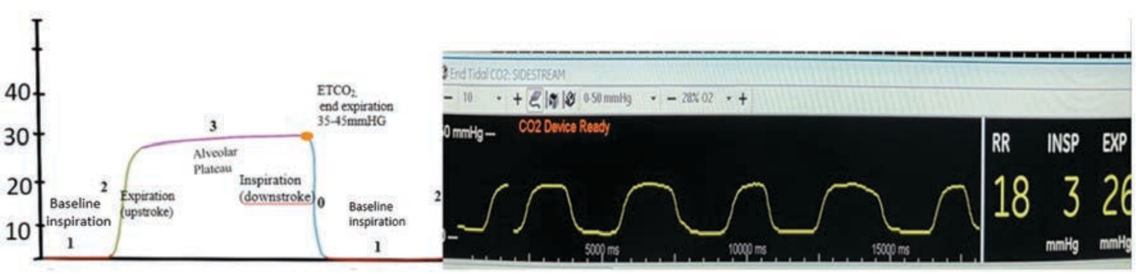

Figure 4. An illustration and waveform capnography pattern of hyperventilation. Note that the $ETCO_2$ is <35 mmHg.

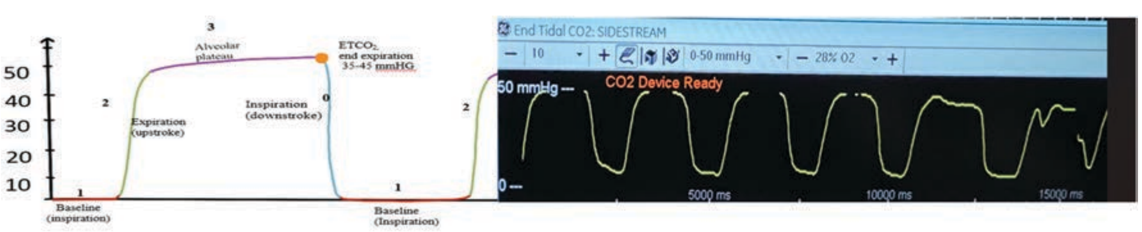

Figure 5. An illustration and waveform capnography pattern of hypoventilation. Note that the $ETCO_2$ is >45 mmHg.

trending of $ETCO_2$ should be consistent. A normal range is found in patients with no metabolism, ventilation, or perfusion problems. Although ventilation rates vary based on age, normal readings for quantity, shape, and trends are the same for men and women of all age groups, making it easy to remember.[7,8]

Quantity: A normal $ETCO_2$ range should be 35-45 mmHg. Over 45 mmHg represents hypoventilation and under 35 mmHg represents hyperventilation.

Rate: A normal respiratory rate should be should be 12-20 breaths per minute (bpm) for adults if the patient is breathing on their own. Ventilating too quickly will not let enough CO_2 build up in the alveoli, resulting in lower $ETCO_2$ readings. Ventilating too slowly will allow extra CO_2 to build up, resulting in higher readings.[7,8]

Shape: The normal shape of the waaveform should normally be a squared-off waveform with rounded corners. Variant waveform shapes can indicate pathology.

Trend: There should be a consistent pattern of activity for a waveform, just like any other vital sign. Abrupt changes can indicate problems with perfusion, breathing and metabolism.

2) For *an intubated patient*, PQRST represents:

Proper tube placement: Capnography assists in determining proper endotracheal tube placement, by identifying normal $ETCO_2$ and respiratory rates, and consistent trends with these measurements.[1,3,7,8]

Quantity: Proper endotracheal tube placement is associated with an $ETCO_2$ between 35-45 mmHg.

Rate: The usual respiratory rate for an intubated patient is between 10-12 breaths per minute.

Shape: The waveform capnography should trend from zero to 35-45 mmHg, with a consistent alveolar plateau. Changes in the plateau section may be associated with displacement or leaks of the of the endotracheal tube.

Trend: There should be consistent numbers for each breath. Abrupt changes require immediate intervention to ensure that the endotracheal tube has not been displaced, or that the patient has not become unstable.

3) In *pulseless ACLS* scenarios, PQRST is used to assess the effectiveness of CPR and the return of spontaneous circulation (ROSC). Code teams use PQRST in the following ways:[2,3,7,8]

Proper: Position of the endotracheal tube should be confirmed using waveform capnography.

Quality: Effective chest compressions should have capnography of 10-20 mmHg, with closer to 20 mmHg being optimal. This indicates effective perfusion and cardiopulmonary resuscitation (CPR). Capnography can also minimize disruptions in CPR for pulseless electrical activity (PEA) arrythmia.

ROSC: When performing CPR and ACLS, an abrupt increase in waveform capnography to 35-45 mmHg indicates ROSC.

Strategy: What treatments are indicated to preserve ROSC and stabilize the patient post resuscitation? (Treatment strategies can include medications, airway support, hypothermia protocols, etc.)

Termination: Codes are terminated due to ROSC or inability to resuscitate the patient. A carbon dioxide level of 10 mmHg or less measured 20 minutes after the initiation of ACLS accurately predicts death in patients with cardiac arrest that have electrical activity but no pulse.

Advantages of Using Capnography in the Lab

In many cath labs, pulse oximetry and visual observation are used to monitor the effects of procedural sedation and narcotics, and to prevent hypoxemia. While oxygenation is accurately assessed with pulse oximetry, capnography provides information on ventilation, perfusion, and metabolism.[9-11] Because of this capability, waveform capnography supplements pulse oximetry, and provides a critical advantage over standalone pulse oximetry, as it detects hypoventilation earlier. It also optimizes respiratory monitoring for patients in the cath who may have

Waveform capnography is highly recommended by the American Heart Association to determine the effectiveness of CPR and ROSC during a code.

TABLE. PQRST Assessment.

Baseline Assessment	Intubation	ACLS
Proper QRST	Proper tube position	Proper tube position
Quantity (35-45 mmHg)	Quantity (35-45 mmHg)	Quality of CPR (10-20 mmHg)
Rate 12-20 bpm	Rate (10-12 bpm)	ROSC (abrupt increase to 35-45 mmHg)
Shape (squared off)	Shape (squared off)	Strategy for further treatment
Trend (consistency)	Trend (consistency)	Termination of compressions

An overview of the three PQRST acronyms used to support patient care delivery
Bpm = breaths per minute; CPR = cardiopulmonary resuscitation; ROSC = return of spontaneous circulation

sleep apnea, chronic obstructive pulmonary disease (COPD), and other airway diseases.

The effectiveness, frequency, and regularity of ventilation and breathing, which is seen on waveform capnography, is detected immediately, and is more predictive than visual observation and pulse oximetry.[9-11] This is especially true in in oxygenated patients, where it may take several minutes for major respiratory changes to register due to passive oxygen movement through tissues.[1,9-11] Waveform capnography will see an immediate change in the waveform that indicates hypoventilation and possible apnea. Therefore, waveform capnography offers another tool to keep patients safe during procedures where conscious sedation and narcotics are administered. It is also valuable for ACS patients, as it can rapidly detect potentially life-threatening changes in breathing, perfusion, and metabolism.

Capnography for ACLS

Waveform capnography is highly recommended by the American Heart Association to determine the effectiveness of CPR and ROSC during a code. During CPR, $ETCO_2$ values mainly depend on the blood flow generated by chest compressions, on ventilation rate and tidal volume, and on the metabolic activity of the patient tissues.[3,11,12] This can be easily seen on waveform capnography. Measurement of a low $ETCO_2$ value (<10 mmHg) during CPR in an intubated patient means that the chest compressions are not effective. High quality chest compressions are achieved when the $ETCO_2$ value is at least 10-20 mmHg, and closer to 20 mmHg is optimal.[2,3,11,12] $ETCO_2$ is the earliest indicator of ROSC and when the heart restarts, there is a dramatic increase in cardiac output, perfusion, and a rapid increase in $ETCO_2$ to 35-45 mmHg.[1,2,10-12] Waveform capnography also helps to prevents unnecessary interruptions for patients in PEA, and avoids unnecessary chest compression and drug administration to patients with spontaneous circulation.[2,3,11-13]

Waveform capnography monitoring systems are easy to set up and waveform interpretation skills can be achieved with a minimal amount of training.

Conclusion

Waveform capnography is an important monitoring tool used throughout healthcare. It complements pulse oximetry, and detects changes in respiratory status before pulse oximetry does. It is also highly useful when intubating patients, and in the management of pulseless ACLS scenarios. Waveform capnography monitoring systems are easy to set up and waveform interpretation skills can be achieved with a minimal amount of training. Waveform capnography offers another tool to effectively monitor patients and promote a culture of safety in the cath lab. ■

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Test your understanding of waveform capnography. A quiz is available online with the article:

Cath Lab Digest

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