Medical Control Guideline: CAPNOGRAPHY

PURPOSE: To describe use of capnography for 911 responses and for inter-facility transfers.

DEFINITIONS:

Capnography: Analysis and recording of carbon dioxide (CO_2) concentrations in respiratory gases via continuous waveform.

Capnometry: Measurement of the amount of carbon dioxide in exhaled air. This gives a specific value for the end-tidal CO_2 measurement.

Colorimetric CO_2 device: Device that changes color due to a chemical reaction in the presence of CO_2, which can be used to detect CO_2 in exhaled air in order to confirm placement of an advanced airway.

End-Tidal CO_2 ($ETCO_2$): The amount of carbon dioxide measured at the end of exhalation.

PRINCIPLES:

1. Ventilation is an active process, which is assessed with end-tidal CO_2 measurement. End-tidal CO_2 measurement is an indication of air movement in and out of the lungs. The normal value of exhaled CO_2 is 35-45mmHg.

2. Oxygenation is a passive process, which occurs by diffusion of oxygen across the alveolar membrane into the blood. The amount of oxygen available in the bloodstream is assessed with pulse oximetry.

3. Capnography provides both a specific value for the end-tidal CO_2 measurement and a continuous waveform representing the amount of CO_2 in the exhaled air. A normal capnography waveform is square, with a slight upslope to the plateau phase during exhalation. (See figures below) The height of the waveform at its peak corresponds to the $ETCO_2$.

4. Capnography is necessary to monitor ventilation. For patients requiring positive pressure ventilation, capnography is most accurate with proper mask seal (two-hand mask hold for adults during bag-mask ventilation) or with an advanced airway.

5. Capnography can also be applied via a nasal cannula device to measure end-tidal CO_2 in the spontaneously breathing patient. It is useful to monitor for hypoventilation, in patients who are sedated either due to ingestion of substances or treatment with medication with sedative properties such as midazolam or opioids. In a patient with suspected sepsis, an $ETCO_2$ <25mmHg further supports this provider impression.

6. Capnography is standard of care for confirmation of advanced airway placement. Unlike simple colorimetric devices, capnography is also useful to monitor the airway position over time, for ventilation management, and for early detection of return of spontaneous circulation (ROSC) in patients in cardiac arrest.

7. Capnography is the most reliable way to immediately confirm advanced airway placement. Capnography provides an instantaneous measurement of the amount of CO_2

in the exhaled air and absence of waveform and/or values <10mmHg suggest possible advanced airway misplacement. However, patients in cardiac arrest or profound shock may also have end-tidal CO_2 values <10 despite proper airway placement.

8. Capnography provides the most reliable way to continuously monitor advanced airway position. The waveform provides a continuous assessment of ventilation over time. A normal waveform which becomes suddenly absent suggests dislodgement and requires clinical confirmation.

9. The value of exhaled CO_2 is affected by ventilation (effectiveness of CO_2 elimination), perfusion (transportation of CO_2 in the body) and metabolism (production of CO_2 via cellular metabolism). In addition to the end-tidal CO_2 value, the ventilation rate as well as the size and shape of the capnograph must be used to interpret the results.

10. Decreased perfusion will reduce the blood flow to the tissues, decreasing offload of CO_2 from the lungs. Therefore, patients in shock and patients in cardiac arrest will generally have reduced end-tidal CO_2 values.

11. A sudden increase in perfusion will cause a sudden rise in end-tidal CO_2 values and is a reliable indicator of ROSC. It is common to have an elevated $ETCO_2$ reading after ROSC. Hyperventilation is harmful and should not be done to in attempt to normalize the $ETCO_2$.

12. Ventilation can have varied effect on CO_2 measurement. Hyperventilation will reduce end-tidal CO_2 by increasing offload from the lungs. Disorders of ventilation that reduce CO_2 elimination (e.g., COPD), will cause CO_2 to build up in the body, increasing the measured value once ventilation is restored. Generally, hypoventilation will increase measured end-tidal $CO_{2,}$ values by decreasing offload from the lungs. However, in patients with decreased tidal volumes, hypoventilation can also reduce end-tidal CO_2, because of the relative increase in dead space.

13. End-tidal CO_2 can be detected using a colorimetric device ($ETCO_2$ detector). These devices provide limited information about $ETCO_2$ as compared to capnography. Colorimetric devices do not provide continuous measurement of the value of CO_2 in the exhaled air and cannot be used in ongoing monitoring. Colorimetric devices should only be used for confirmation of endotracheal tube placement if capnography is unavailable due to equipment failure.

GUIDELINES:

1. Capnography shall be used for ALL patients receiving positive-pressure ventilation (BMV or advanced airway). Utilize the capnography waveform to assess the patient's ventilation and perfusion status. Refer to the figures below for examples of typical waveform tracings.

2. Always attach the capnography device to the monitor first and wait for the capnography display to appear prior to applying the device to the patient. This zeros the device to ensure an accurate reading.

3. Apply the capnography device immediately upon initiating any positive-pressure ventilation, or as soon as feasible.

4. During bag-mask-ventilation, maintain a continuous seal in order to obtain accurate capnography readings.

5. When an advanced airway is placed, the capnography device shall be applied/re-applied immediately to confirm airway placement, along with assessing bilateral breath sounds and absence of gastric sounds.

6. Visualization of a normally shaped waveform with a normal or elevated value confirms placement. Extremely low values (<10 mmHg) without the typical waveform implies esophageal placement and the endotracheal tube should be removed. For patients in shock or cardiac arrest, the value (and height of the waveform) will likely be reduced but the shape of the waveform should be normal.

7. Continuously monitor the waveform, report the capnography reading to the base hospital and document capnography reading on the patient care record as follows:

   a. Immediately after placement of an advanced airway
   b. With any change in patient condition
   c. After any patient movement
   d. Every five minutes during transport
   e. Upon transfer of care

8. For patients in cardiac arrest, continuously monitor capnography during resuscitation. A sudden rise in $ETCO_2$, along with an organized rhythm, is a reliable sign of ROSC and should prompt a pulse check. Do not hyperventilate regardless of the $ETCO_2$ value; elevated values will normalize with proper ventilation. A drop in $ETCO_2$ below normal can signify progressive hypotension or re-arrest.

9. Consider use of capnography via nasal cannula, if available, in spontaneously ventilating patients who are:

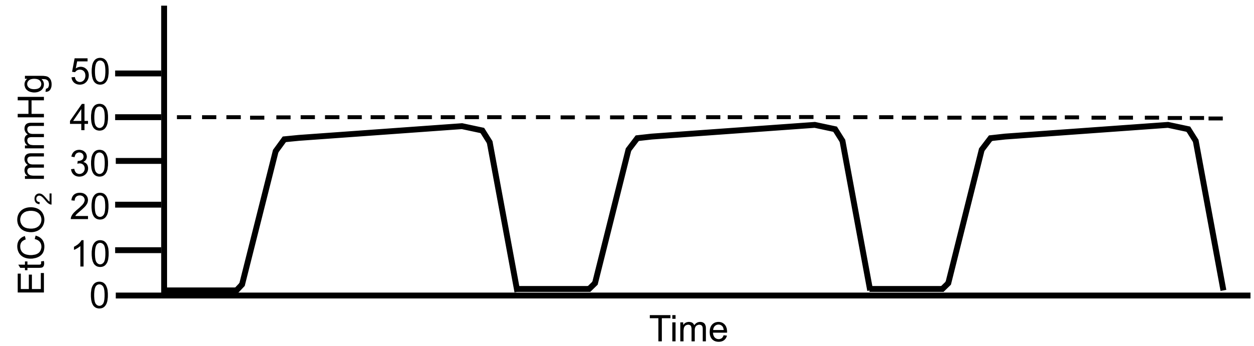
   a. Sedated due to illicit substance ingestion
   b. Treated with medications with sedative properties (e.g., midazolam or opioids)
   c. In severe respiratory distress

10. In spontaneously breathing patients, monitor for significant hypoventilation or apnea as an indication to begin assisted ventilation. A “shark-fin” waveform on $EtCO_2$ monitoring indicates bronchospasm; treatment with albuterol is indicated.

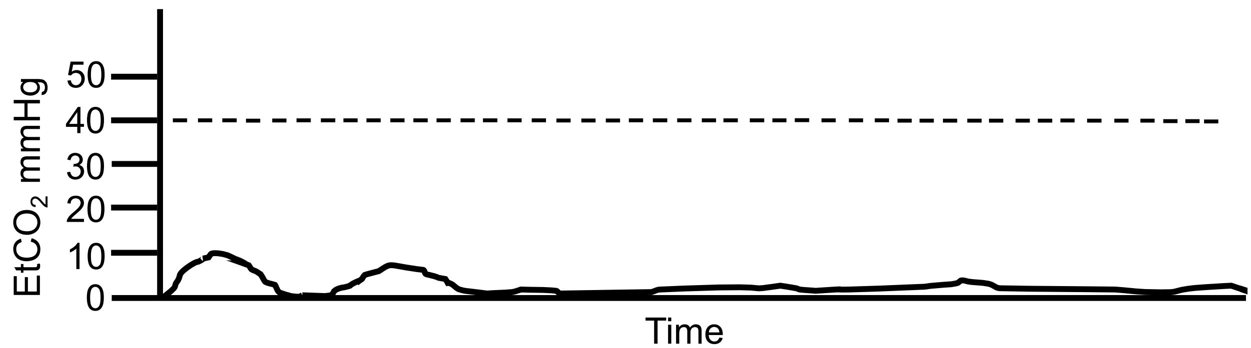
11. During positive-pressure ventilation, if a “shark-fin” pattern and/or an elevating $EtCO_2$ waveform (“breath stacking”) is visualized, decrease ventilation rate to avoid increases in intrathoracic pressure which can lead to decrease in venous blood return to the heart and cardiopulmonary arrest.

Capnography Waveforms

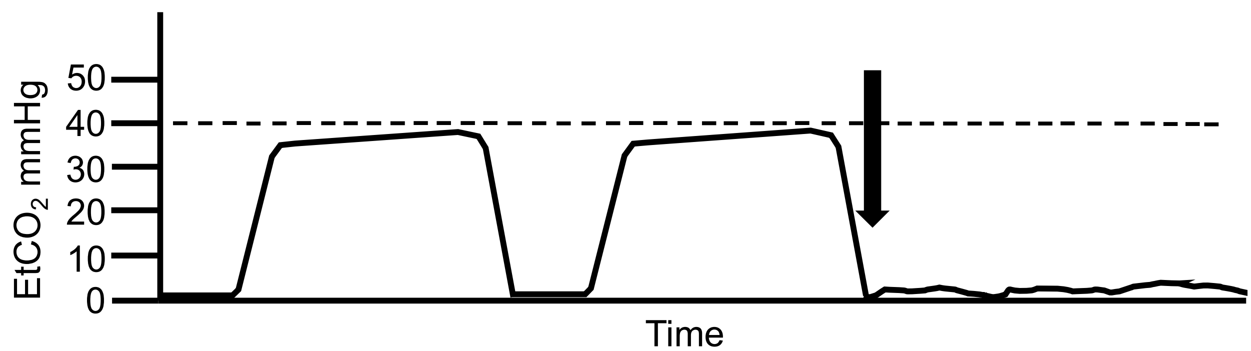
Normal shape of the capnograph (Normal waveform is depicted below)



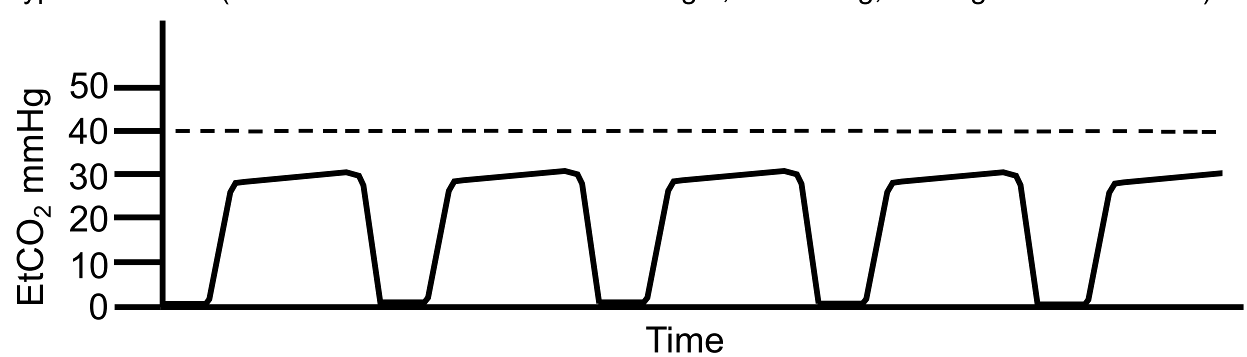
Esophageal Intubation (Low values <10 and irregular waveform or flat line)



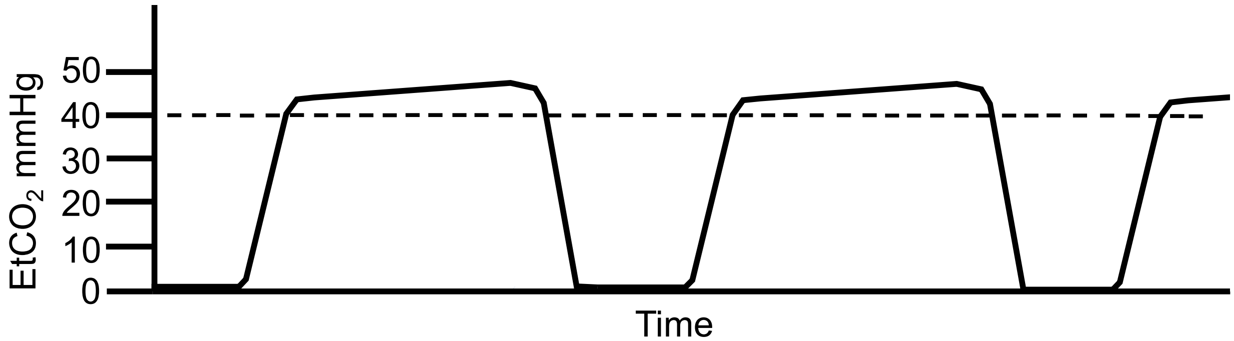
Obstructed or Dislodged Endotracheal Tube (Sudden loss of normal waveform followed by low irregular waveform or flat line)



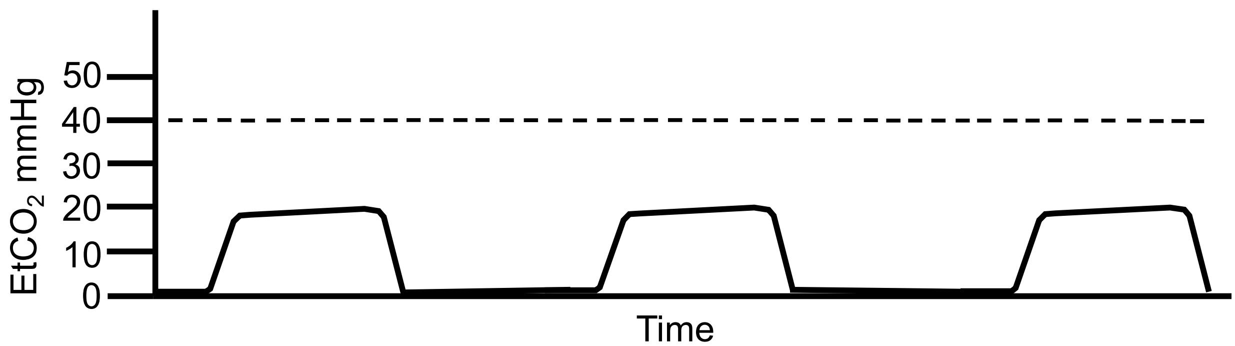
Hyperventilation (Normal waveform with reduced height, <35mmHg, and high ventilation rate)



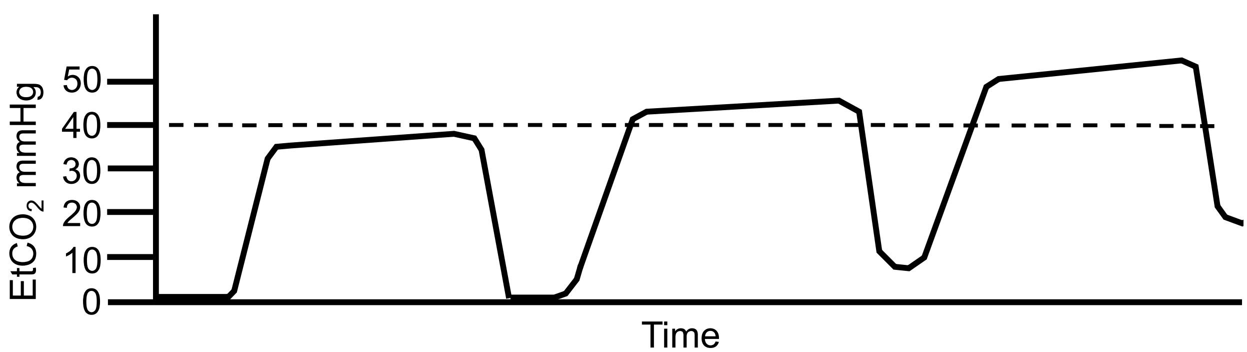
Hypoventilation / Bradypnea (Normal waveform with increased height, >45mmHg)



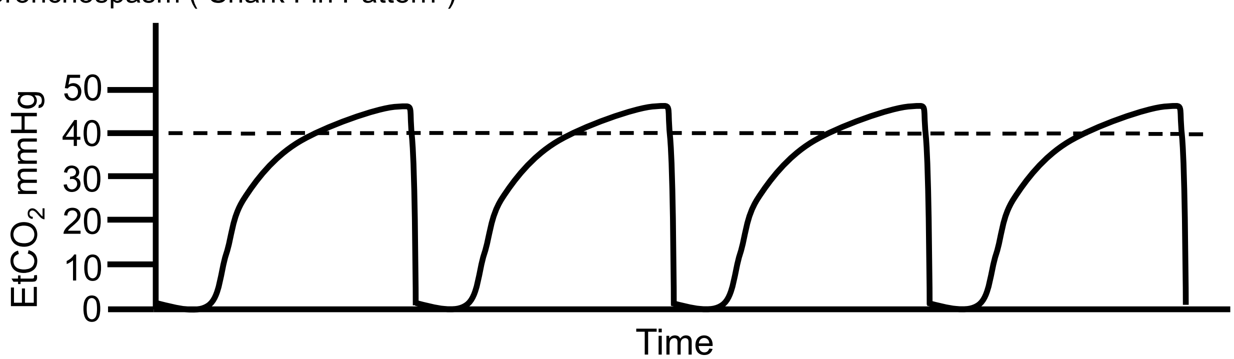
Hypoventilation / Low tidal volumes (Normal waveform with reduced height, <35mmHg, and slow ventilation rate; A similar reduced height waveform can also be seen with shock – see progressive hypotension below).



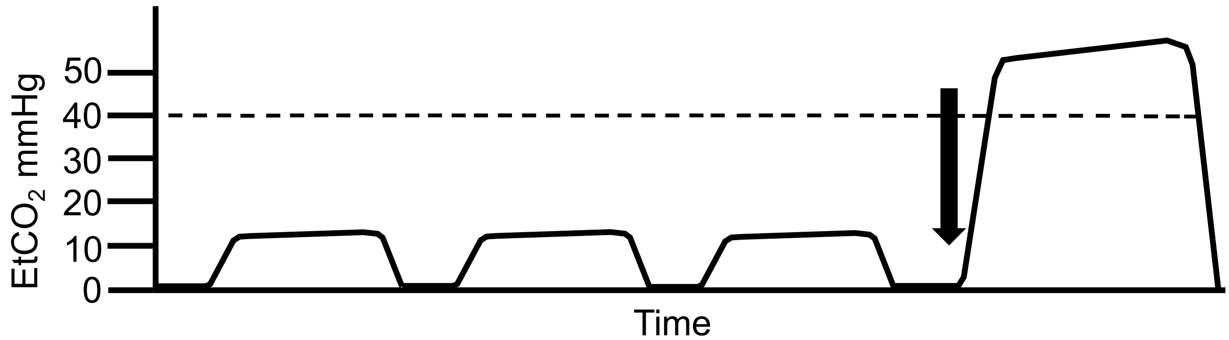
Air Trapping / Breath Stacking (Box wave forms that show increasing values with each successive breath)



Bronchospasm ("Shark Fin Pattern")



Return of Spontaneous Circulation (Sudden increase in values in a patient in cardiac arrest)



Progressive Hypotension or Re-arrest (Progressive decrease in values with each successive breath)