A Vital Adjunct for Improved Patient Safety and Outcomes

WAVEFORM CAPNOGRAPHY FOR OHIO EMS

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Patient Assessment Concerns

- Adequate oxygenation
- Adequate ventilation
- Adequate perfusion

Oxygenation

- Adequate oxygenation is vital for end organ and tissue function and metabolism
- Assessment of the oxygenation of a patient with respiratory symptoms or distress should ideally be continuous, rather than intermittent, during patient treatment and transport

Ventilation

- Encompasses the inhalation and exhalation cycles of respiration
- Adequacy of ventilation is determined by how effective the lungs transfer oxygen (O_2) to and remove carbon dioxide (CO_2) from the body
- Inadequate ventilation can be the first sign of impending respiratory failure or respiratory arrest

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Perfusion

- The adequacy of oxygen delivery via the blood to proximal and distal tissues in the body
- Commonly assessed by:
  - Blood pressure
  - Strength of the pulse
  - Location of the pulse
  - Capillary refill

Perfusion

- Clinical assessment can be affected by:
  - Intravascular volume
  - Ambient temperature
  - Patient's core temperature
  - Cardiopulmonary disease or dysfunction
  - Sepsis
  - Neurologic disease or injury

Pulse Oximetry

Benefits

- Colorimetric digital measurement of the percentage of oxygenated hemoglobin
- Can provide continuous measurements
- Non-invasive
- Now considered "the fifth vital sign"

Limitations

- Readings may be within the normal range in the presence of abnormal CO_2 exchange
- Can be inaccurate or unobtainable in the presence of poor perfusion
- May not rapidly detect displaced or improperly placed invasive airway devices

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Pulse Oximetry

- Measures the saturation of hemoglobin
- Does not measure CO_2 levels and, therefore; may be inadequate to accurately assess adequacy of ventilation
- Remains a valuable solitary airway assessment tool for stable patients that require no or minimal non-invasive airway support and/or medical treatment

End Tidal Carbon Dioxide ($ETCO_2$)

- The partial pressure or maximum concentration of carbon dioxide at the end of an exhaled breath
- Can be used as an adjunct to assess adequacy of ventilation and/or perfusion
- Methods of measurement
  - Colorimetric $ETCO_2$ detection
  - Digital capnometry
  - Waveform capnography

Colorimetric $ETCO_2$ Detectors

Benefits

- When placed on the end of an invasive airway device, the change in color to indicate CO_2 exchange occurs promptly
- The color changes occur cyclically with each ventilator cycle
- Inexpensive device

Limitations

- Qualitative (not quantitative)
- Colorimetric change of pH-sensitive paper is limited by moisture, duration of use, length of time outside of packaging
- Can be inaccurate in the post-cardiac arrest period and other states of poor perfusion
- Use is limited to patients that have an invasive airway device in place

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Digital Capnometers

Benefits

- Quantitative colorimetric measurement of circulating CO_2 levels
- Application of the device is similar to what is done with a pulse oximeter
- Inexpensive device
- Many digital capnometry devices are also capable of performing pulse oximetry and measuring carbon monoxide (CO) levels

Limitations

- Provides a digital numeric value
- Does <u>not</u> provide a graphic pattern of CO_2 exchange to:
  - Generate a continuous record of the patient's ventilatory status to the receiving facility or to rapidly identify patient deterioration
  - Assist the EMS provider in the determination of the cause of inadequate ventilation or perfusion

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Waveform Capnographs

Benefits

- Provides continuous quantitative measurement of CO_2 levels during entire respiratory cycle (exhalation and inhalation)
- Capable of providing a dynamic graphic record of a patient's ventilatory status
- No absolute contraindications for utilization

Limitations

- More expensive than colorimetric end tidal CO_2 detectors and digital capnometers

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Assessment of Invasive Airway Device Placement

- Direct visualization of the trachea following endotracheal tube placement
- Auscultation of the chest
- Pulse oximetry
- End tidal CO_2 detection

Why is End Tidal CO_2 Important?

- Inadequate airway management leading to hypoxia remains in the **top five** grounds for successful malpractice litigation against EMS providers and EMS agencies
- Pulse oximetry alone can fail to recognize hypoventilation or hyperventilation (particularly in non-intubated patients)

Why is Waveform Capnography Important?

- More rapid recognition of misplaced or displaced invasive airway devices
- In cardiac arrest, continuous quantitative waveform capnography has the additional capabilities of:
  - Monitoring the effectiveness of cardiopulmonary resuscitation (CPR)
  - Early detection of return of spontaneous circulation (ROSC)

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Ohio EMS - **Requirements**

- On December 17, 2014, the State of Ohio Emergency Medical, Fire, and Transportation Services Board approved the mandatory utilization of waveform capnography for all patients requiring invasive airway devices effective **January 1, 2021**

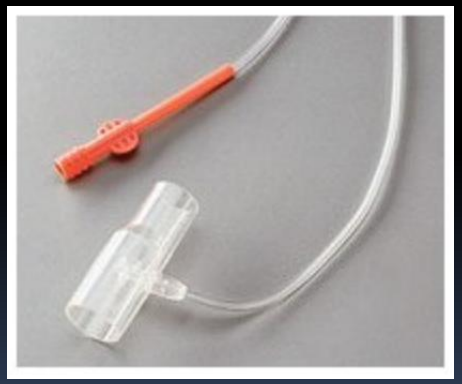
Ohio EMS - Recommendations

- Effectively immediately, the State of Ohio Emergency Medical, Fire, and Transportation Services (EMFTS) Board highly recommends the utilization of digital capnometry or waveform capnography as an assessment tool for all patients who require oxygen via any route of administration

Waveform Capnography

- Stabilization of the patient should always take priority before the application and initiation capnography monitoring
- There are no absolute contraindications to using capnography
- Capnography can be used in pediatric and adult patients

Capnography Equipment



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Waveform Capnography

- The data from a waveform capnograph that can be analyzed includes:
  - Respiratory rate
  - End tidal CO_2 during the entire respiratory cycle (exhalation and inhalation)
  - Morphology of the capnograph tracing produced by continuous monitoring

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Waveform Capnography
End Tidal CO_2 ($ETCO_2$)

- The normal range of $ETCO_2$ is 35-45 mm Hg
- $ETCO_2$ readings within the normal range may indicate:
  - Normal cardiac or pulmonary function
  - Proper placement of an invasive airway device (endotracheal tube or supraglottic airway device)
  - Return of spontaneous circulation (ROSC) as indicated by a sudden rise of $ETCO_2$ to a level greater than 30 mm Hg

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Waveform Capnography
Morphology of the Capnograph

In addition to continuous $ETCO_2$ monitoring, benefits of waveform capnography compared to digital capnometry are:

- Information can be acquired from analysis of the morphology of the capnograph tracing
- The capnograph captures dynamic changes that can occur in the status of the patient's ventilation and perfusion

Waveform Capnography
Normal Capnograph Tracing

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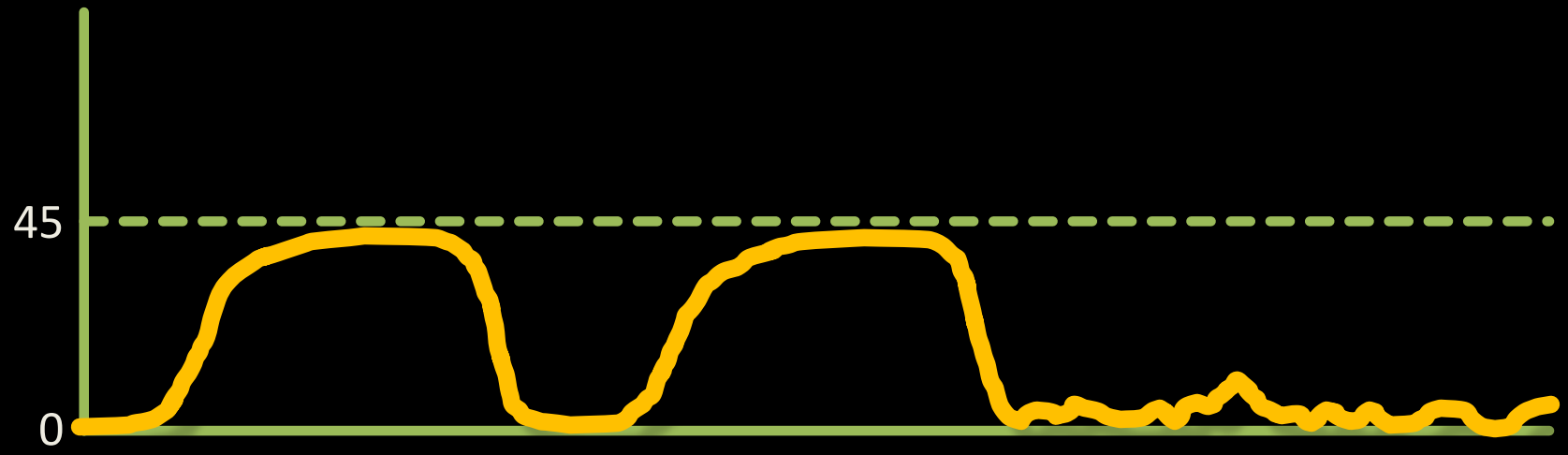
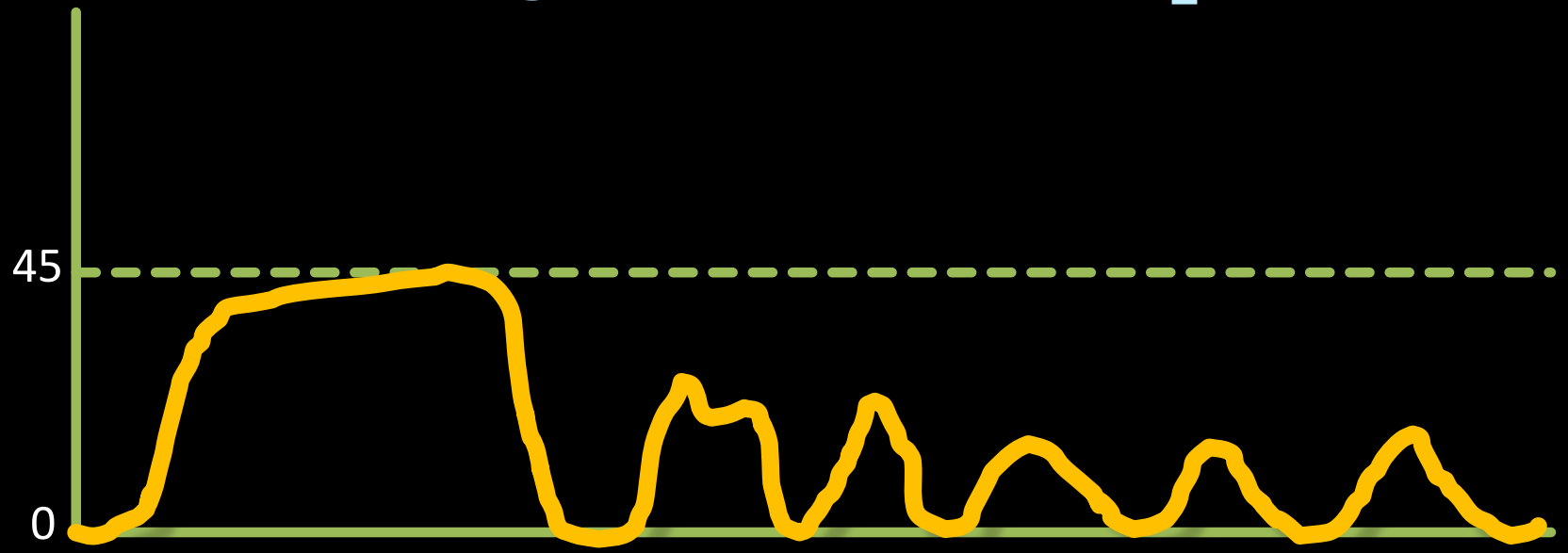
Abnormal Capnograph Tracing
Sudden Loss of Waveform



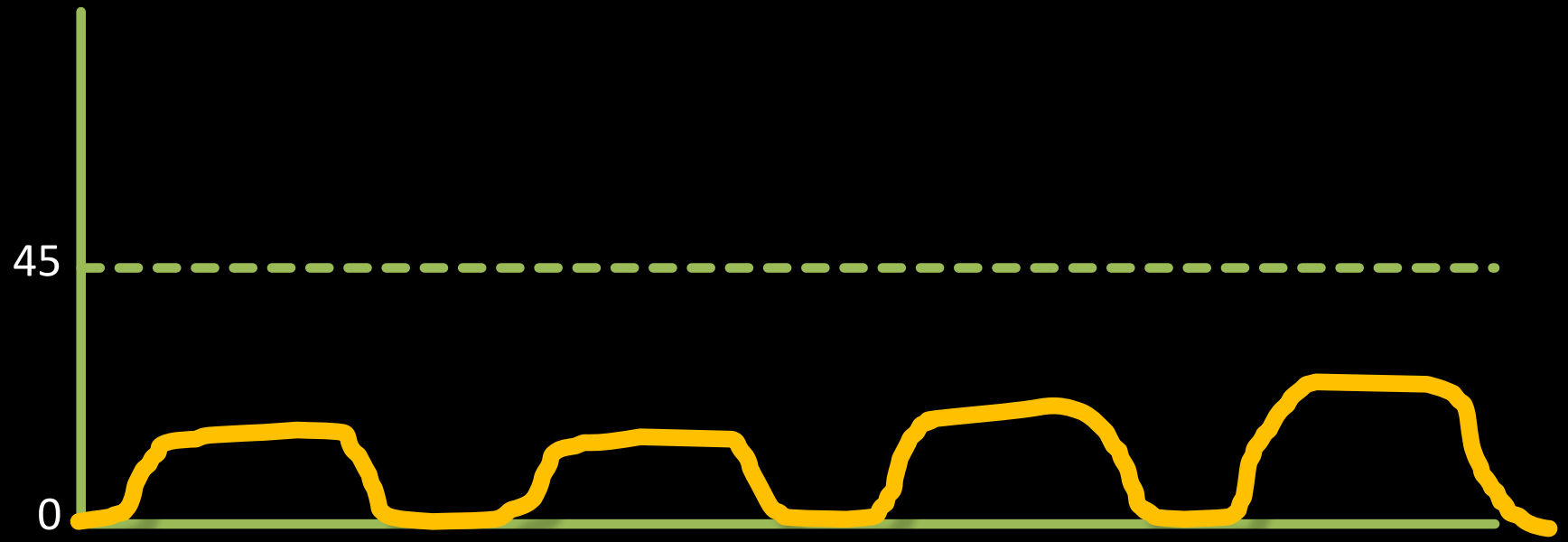
- Invasive airway device disconnected, dislodged, kinked or obstructed
- Loss of circulatory function

Abnormal Capnograph Tracing Decreasing End Tidal CO_2



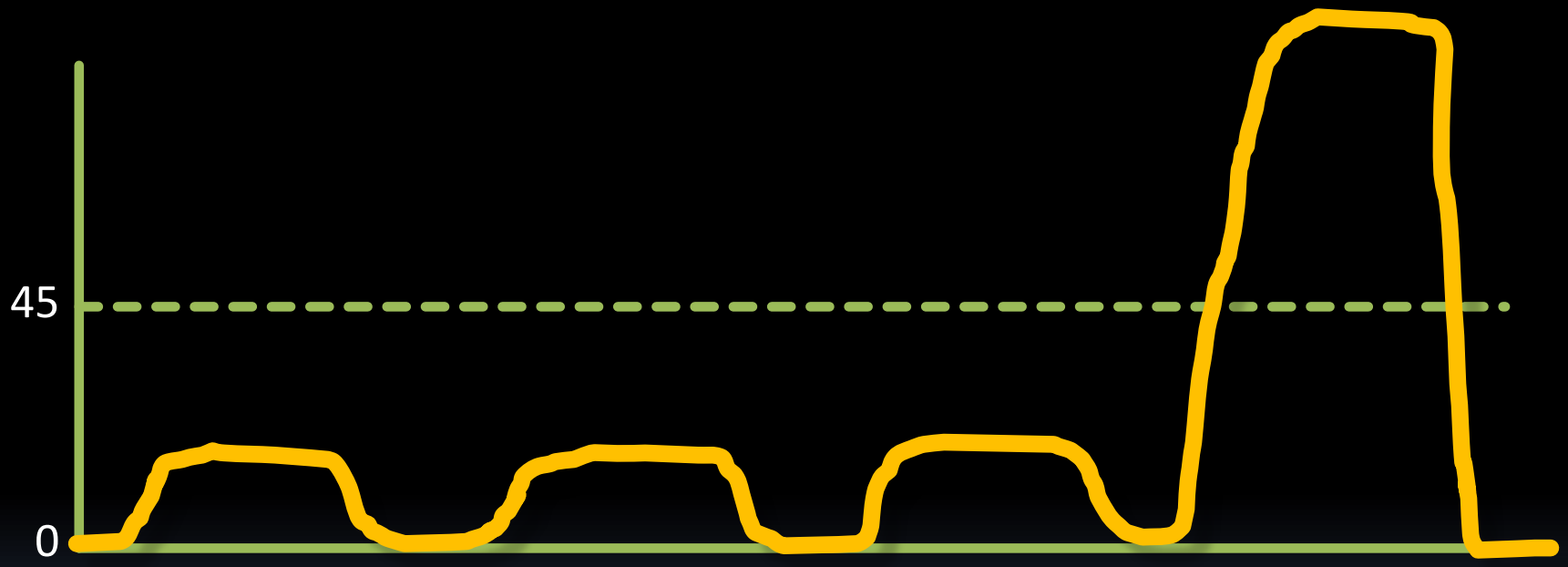
- Endotracheal tube cuff leak
- Invasive airway device in hypopharynx
- Partial obstruction

Abnormal Capnograph Tracing
CPR Assessment



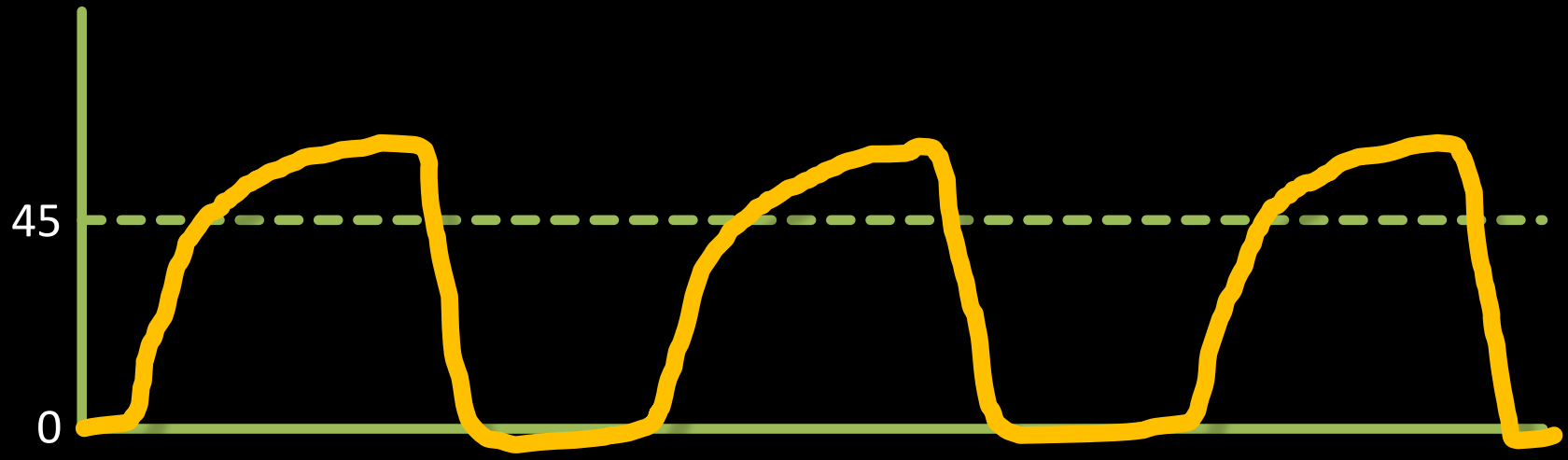
- Attempt to maintain minimum of 10mmHg

Abnormal Capnograph Tracing
Sudden Increase in End Tidal CO_2



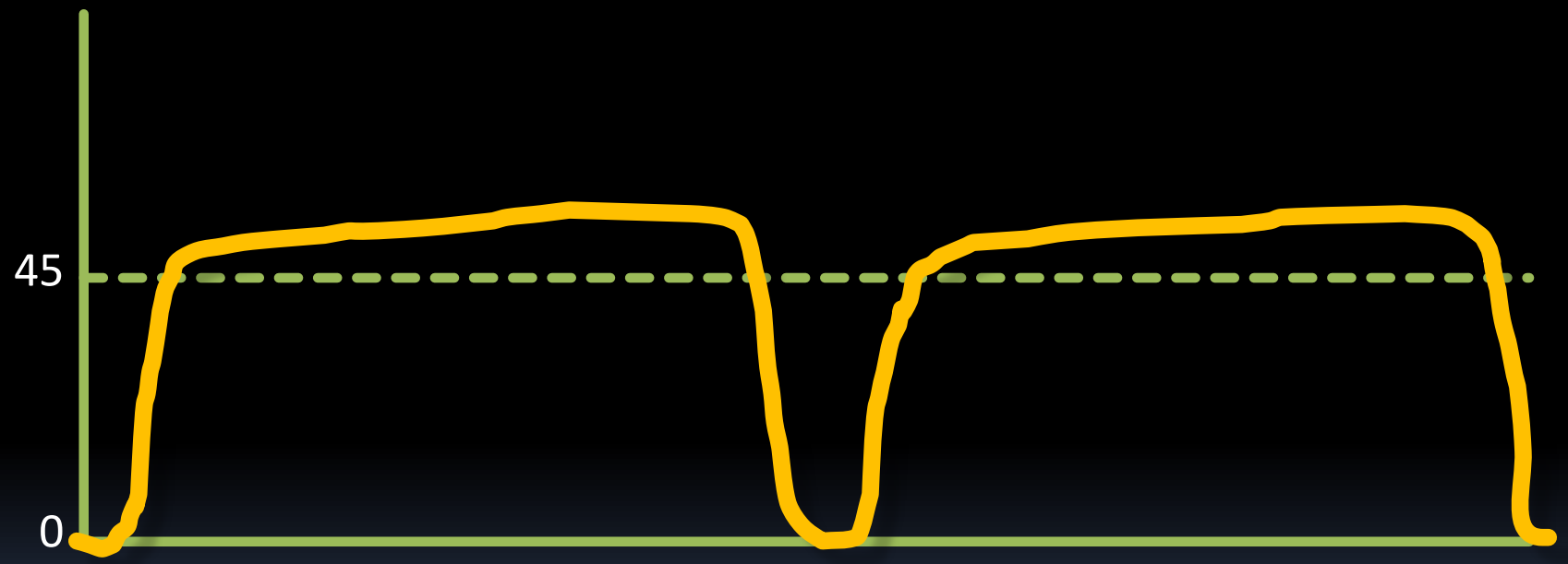
- Return of spontaneous circulation (ROSC)

Abnormal Capnograph Tracing Bronchospasm

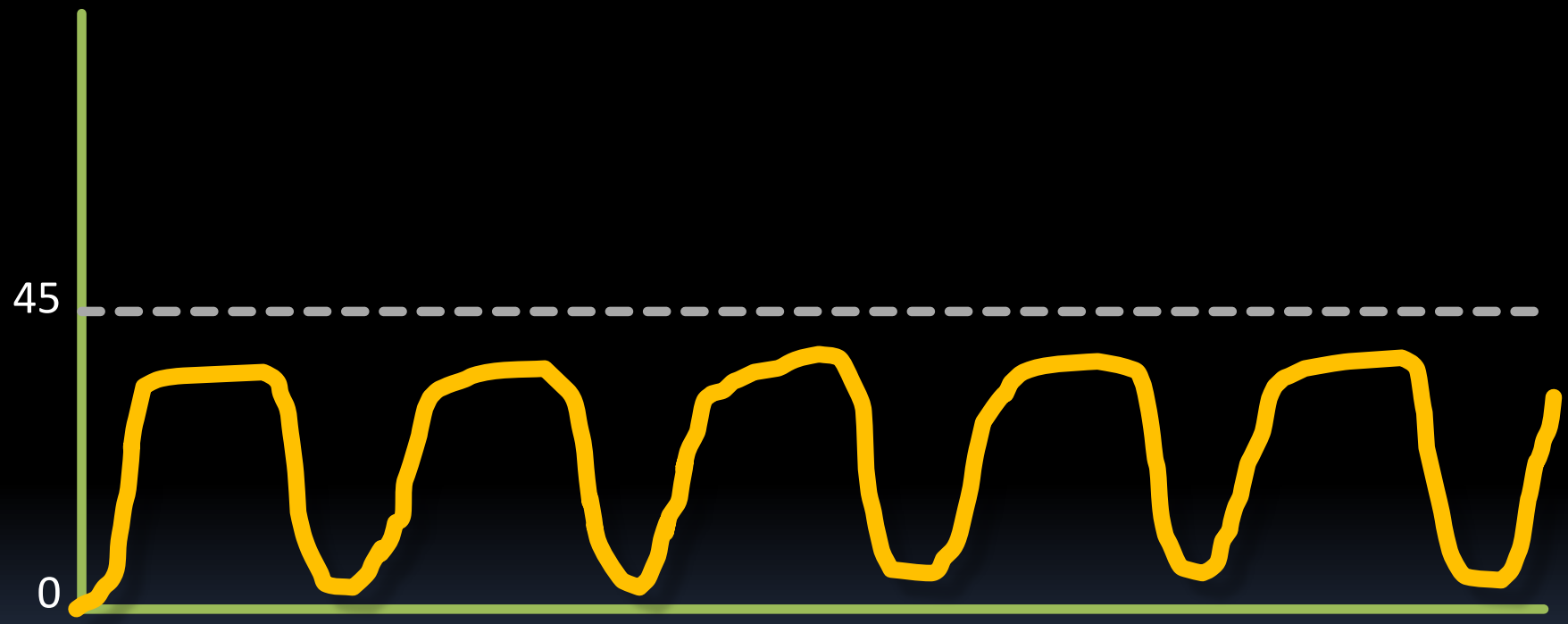


- Asthma
- COPD

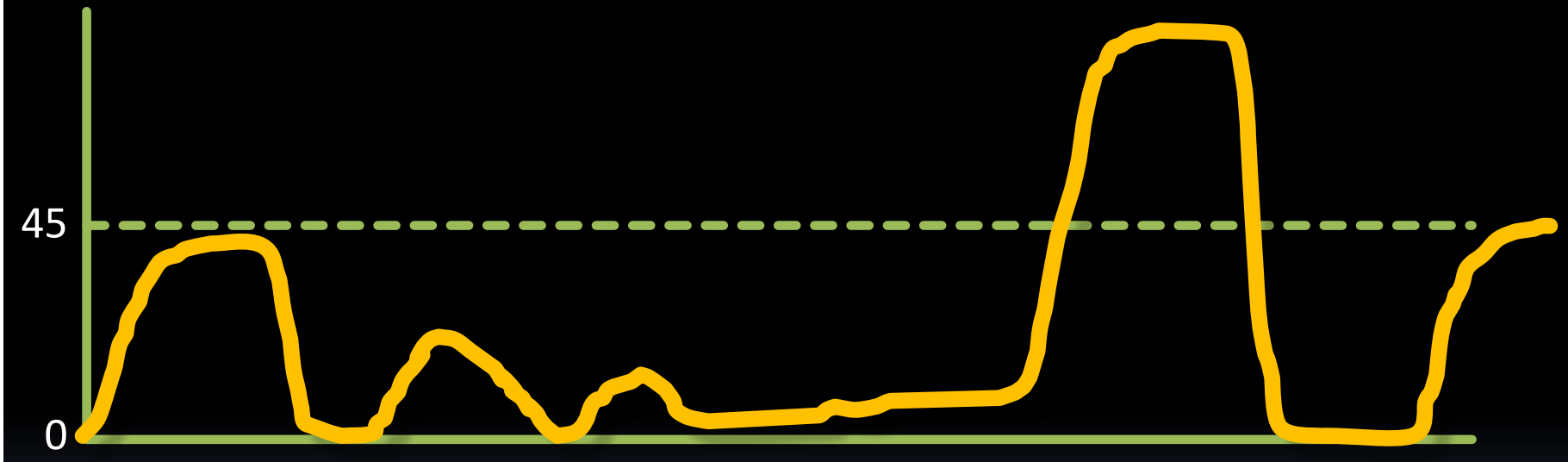
Abnormal Capnograph Tracing Hypoventilation



Abnormal Capnograph Tracing Hyperventilation



Abnormal Capnograph Tracing Decreased End Tidal CO_2



- Apnea
- Sedation

Waveform Capnography Monitoring Tips

- Monitor the capnography waveform
- Any change in waveform displayed on the capnograph could indicate a problem and should be investigated immediately

Waveform Capnography Monitoring Tips

If no or low CO_2 is detected by the waveform capnograph monitor, consider:

- Loss of airway function
  - Apnea
  - Misplaced invasive airway device
- Loss of circulatory function
  - Cardiac arrest
  - Shock
  - Massive pulmonary embolism
- Equipment malfunction
  - Obstruction
  - Displaced invasive airway device

Waveform Capnography Monitoring Tips

- The waveform capnography device should remain in place, along with the appropriate airway device, and monitored for the entirety of patient care and transport
- If the correct placement or function of an invasive airway device remains in question, it is always acceptable and preferable to ventilate the patient with oxygen delivered via a bag valve mask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