Using Capnography to Improve Patient Safety

Lisa Shultis, BS, RRT
Program Director
Mandl School

Objectives

• Discuss the importance of monitoring patients on opioid sedation.
• Define the following terms: capnography, EtCO₂, capnometer.
• Discuss the advantages, disadvantages, and clinical applications of EtCO₂.
• State the physiologic changes in PaCO₂ and EtCO₂ seen during inspiration and expiration.
• Recognize abnormal waveforms and state how they are managed.
• List possible causes for an increase and a decrease in EtCO₂.

Pain Management

Pain Management is Important
• Improves patient satisfaction
• Decreases recovery time
  • But it is equally important that continuous respiratory monitoring be maintained to avoid opioid-induced respiratory depression resulting in hypoxia

Pain Management

Opiates represent one of the four drug categories that cause more than 60% of serious adverse events in the United States

National Error Reporting Database, MEDMARX
**Patient Controlled Analgesia (PCA)**

An effective method for patient self-administration of opiates for pain relief

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**PCA: The Current Practice**

Standard assessment tools for measuring patient sedation:

- Respiratory Rate
  - May improve with stimulation, but will revert to lower levels when stimulation stops.
- Oxygen Saturation
  - Does not give adequate forewarning of impending hypoxia caused by postoperative ventilatory depression.
- Sedation Scale

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**Ramsay Sedation Scale**

1. Is anxious/agitated/restless
2. Is co-operative, oriented, and tranquil
3. Responds to commands only
4. Exhibits brisk response to light glabellar tap or loud auditory stimuli
5. Exhibits sluggish response to light glabellar tap or loud auditory stimuli
6. Exhibits no response

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**But Are Our Current Practices the Best Practice?**

Faces of Tragedy
The Case That Set a New Standard

Changing Practice Standards

The Center for Medicare and Medicaid forecasts that between 2010 and 2020, the average annual health spending growth will outpace the annual growth in the overall economy by 4.7% and comprise 19.8% of the Gross Domestic Product (GDP).

(CMS, 2009)

Richard Tseng vs. Mazzacco Ambulatory Surgery Ctr, Case No. LC084435

Mr. Tseng underwent eye surgery for a prosthetic lens implant.

- Midazolam, fentanyl and propofol were given

His attorneys alleged that Mr. Tseng's injuries could have been prevented with capnography.

The jury awarded $2.25 million in damages.

What is the best way to monitor our patients?
Literature Review

- Incidence of respiratory depression measured by oxygen desaturation was 12%.
  - SpO2 < 90%
- Occurrence of respiratory depression based on bradypnea with capnography monitoring was 58%.
  - Bradypnea defined as > 1, two-minute or longer low-RR event [RR< 10 bpm]

Overdyk, et al., 2007

Capnography

- Measures in real-time the adequacy of ventilation.
  - Intubated or tracheostomy tube patients
  - Non-intubated patients receiving PCA therapy
- Facilitates early detection of clinically significant or catastrophic events by:
  - Displaying changes in the amount of CO2 detected
  - Displaying abnormal waveforms

Capnography vs. Pulse Oximetry

**Capnography**
- EtCO2/RR/apneic events
- Reflects ventilation
- Hypoventilation and apnea detected immediately
- Reflects change in ventilation within 10 seconds
- Should be used with pulse oximetry

**Pulse Oximetry**
- Oxygen saturation/HR
- Reflects oxygenation
- SpO2 changes lag when patient is hypoventilating
- Reflects change in oxygenation within 5 minutes
- Should be used with capnography

Why Use Continuous Monitoring with PCA Therapy?

- **Opioid-induced apnea/Undiagnosed sleep apnea:** detected by no breath alarm
- **Post-op pneumonia:** detected by low oxygen saturation alarm
- **Congestive heart failure:** detected by low oxygen saturation alarm
- **Respiratory depression secondary to opioid overdose:** detected by all of the following:
  - Low oxygen saturation alarm
  - High EtCO2 alarm
  - Low respiratory rate alarm
  - No breath alarm
St Joseph’s/Candler Hospitals (Savannah, Georgia)

What Happened:
- 3 significant patient events in less than 2 year period

What They Did:
- In 2004, replaced its existing traditional IV pumps with “smart” IV safety systems - PCA pump with integrated capnography

Microstream® CO2 Sampling

Small pin holes deliver pillow of oxygen around both nose and mouth

Uni-Junction™ of sampling ports prevents dilution from non-breathing source

PCA/Oximetry/Capnography System

System provides accurate EtCO2 readings for non-intubated patients that receive supplemental oxygen and switch between oral and/or nasal breathing

Maximum oxygen flow rate of 5 LPM

Unique delivery method reduces CO2 sampling dilution

Works effectively under oxygen delivery mask
Problems with Non-invasive Capnography

- Compliance with use
- Dislodgement of devices
- False or “nuisance” alarms
- Restricted patient mobility

Definitions

- Capnogram – a graphical display of carbon dioxide partial pressure over time
- Capnometer – a numeric value of the carbon dioxide partial pressure
- Capnography – the continuous measurement and graphic display of the carbon dioxide level in the exhaled breath

The Capnogram

Visual assessment of patient airway integrity
- Height shows amount of exhaled carbon dioxide
- Length depicts time
The shape of a capnogram is identical in all humans with healthy lungs.
Any deviations in shape must be investigated to determine a cause of the abnormality

Types of Monitors

Side-stream
- Sampling tube continually pumps small volume of gas from vent circuit into analysis chamber within the device

Mainstream
- In-line analysis chamber between the patients airway and the vent circuit
Normal Ventilation Waveform

Normal CO2 waveforms must have all of the following components:

A. Zero baseline
B. Rapid, sharp expiratory uprise
C. Alveolar plateau
D. Well-defined end-tidal point
E. Rapid, sharp inspiratory downstroke

Normal Values

Normal PaCO2 is 35 – 45 mmHg

Normal End-tidal CO2 is normally 35 – 43 mmHg
- PETCO2 is 1 to 5 mmHg lower than PaCO2 due to the mixing of VDalv with VDanat

Fractional Inspired Carbon Dioxide (FiCO2) is 0 mmHg
- This is the “0” baseline on the capnograph

Capnography: Abnormal Tracings

Hypoventilation

Clinical findings:
- Slow breathing, high EtCO2

Possible causes:
- Increased sedation, overmedication
- Snoring or possible obstruction

Possible responses:
- Follow hospital protocol
- Assess Airway, Breathing and Circulation (ABC’s)
- Assess sedation level (Administer Narcan?)
- Stimulate patient
- Notify prescribing physician

Call the rapid response team if no improvement is noted
**Capnography: Abnormal Tracings**

**Hyperventilation**

Clinical findings:
- Rapid breathing, low EtCO₂
Possible causes:
- Increase in pain level or splinting
- Increase in anxiety or fear
- Respiratory distress or shortness of breath
Possible responses:
- Follow hospital protocol
- Assess ABC’s
- Treat cause of increased RR (Decrease pain stimulus)
- Notify prescribing physician
Call the rapid response team if no improvement is noted

**Loss of Waveform**

Clinical findings:
- Very shallow or no respiratory rate pattern
- Sudden loss of EtCO₂ reading
Possible causes:
- No breath or apnea
- Very shallow breathing
- Overmedication or sedation
- Displaced cannula
Possible responses:
- Follow hospital protocol
- Assess ABC’s/Open airway
- Stimulate patient
Call the rapid response team if no improvement is noted
Capnography: Abnormal Tracings

Cardiogenic Oscillations

Clinical findings:
- Low respiratory rate

Possible causes:
- Small gas movements created largely by the pulsations of the aorta and the heart.
- Very shallow breathing
- Overmedication or sedation
- Displaced cannula

Possible responses:
- Follow hospital protocol
- Assess ABC's/Open airway
- Stimulate patient

Call the rapid response team if no improvement is noted

Loss of Alveolar Plateau

Clinical findings:
- Wheezing
- Difficulty breathing

Possible causes:
- Bronchoconstriction
- Asthma/COPD
- Incomplete exhalation/airway obstruction
- Blocked sampling tube

Possible responses:
- Follow hospital protocol
- Assess ABC's/Bronchodilator
- Stimulate patient

Call the rapid response team if no improvement is noted
**Elevated Baseline**

**Clinical findings:**
- Rebreathing CO2

**Possible causes:**
- Oxygen device has inadequate oxygen flow
- Overmedication or sedation
- Air trapping (COPD/Asthma)
- Displaced cannula

**Possible responses:**
- Follow hospital protocol
- Assess ABC’s/Open airway
- Stimulate patient

Call the rapid response team if no improvement is noted.

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**Capnography: Abnormal Tracings**

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**Curare Cleft**

**Clinical findings:**
- Return of spontaneous ventilation after neuromuscular junction blocking drug administration

**Possible causes:**
- Neuromuscular blockade wears off

**Possible responses:**
- Consider neuromuscular blockade re-administration

**Can be seen on intubated patients placed on capnography**
**EtCO₂ Alarms**

**Low EtCO₂ Alarm:** Possible causes:
- True measurement, disposable not correctly attached to patient

**High EtCO₂ Alarm:** Possible causes:
- True measurement, fever or hypermetabolic state, disposable not correctly attached to patient

**High FiCO₂ Alarm:** Possible causes:
- Pt. is inspiring exhaled CO₂, disposable not correctly attached to patient, oxygen flow to mask may have stopped, covers may be over patient’s face

**No Breath Detected Alarm:** Possible causes:
- Patient is not breathing, disposable not correctly attached to patient and/or device, disposable not detecting exhaled breath (shallow breath)

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**Case 1**
- A 69 year-old healthy patient is admitted to the med-surg floor following a total knee replacement.
- He received a femoral nerve block prior to OR.
- He is on a Morphine PCA postop: 2 mg dose, 6 minute lockout with a dose limit of 12 mg/hr.
- Two hours after initiating the PCA, his respiratory rate decreases to 8 breaths per minute and his EtCO₂ increases from 35 to 50 mmHg and he is slow to respond to verbal stimuli.

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**Discussion**

- What treatments or interventions would be appropriate for this patient?
- What is the most likely cause for the observed distress?

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**Case 1 (cont)**
- The PCA was restarted two hours later at 1 mg dose with a 6 minute lockout.
- The patient’s respiratory rate was 10 breaths/minute, and EtCO₂ was 25 mmHg.
- One hour later, the EtCO₂ increased to 58 mmHg. The patient responded to verbal stimuli and denied pain.
**Discussion**

- What treatments or interventions would be appropriate for this patient?
- What is the most likely cause for the observed distress?

**Case 2**

- PEtCO2 alarm sounds and RT responds to a patient recovering from a total hip replacement.
- Patient is unresponsive and PETCO2 = 58 mmHg.
- Patient was stimulated and encouraged to deep breathe. MD was notified.
- Patient on PCA demand but no doses of PCA had been administered.

**Return on Investment**

St Joseph’s/Candler Hospitals

- No PCA-related respiratory events with a serious outcome
  - now approaching their 10th ‘event free’ year
- Averted at least 471 preventable adverse drug events
- Prevented estimated potential expenses of almost $4 million
- 5 year ROI of $2.5 million
Changing Technological Uses, Changing Legal Liability

New uses of existing technology and the advent of new technology will expand the standard of care, regardless of the perceived costs involved.

While some medical professionals may feel that the applicable standard of care is in a trial and not a medical panel, who decides what capnography is not cost effective, it is a jury, and not a medical panel, who decides what the applicable standard of care is in a trial.

“Sedation Gone Wrong”

References


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References