Transcutaneous CO2 Monitoring: Alerting the Anesthesia Provider to Impending Respiratory Depression

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Objectives

- Participants will be able to identify risk factors for respiratory depression in the perioperative patient.
- Participants will review the current guidelines and literature supporting respiratory monitoring in the perioperative setting.
- Participants will understand the accuracy of the transcutaneous CO2 monitoring technology.
- Participants will be able to identify uses for the transcutaneous CO2 to monitor for respiratory depression in the intraoperative and postoperative period.
Inpatient stays complicated by respiratory compromise (RC) surpassed $7 billion in 2007\(^1\).

- RC originating on general wards increase hospital length of stay (LOS) by 7 days and ICU LOS by 3 days \(^2\).

- RC will increase average hospital cost by an additional + $18,208 \(^2\).

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Economic Burden: Postoperative Respiratory Failure

- Postoperative Pulmonary Complication: 70.3% of deaths\(^1\)
- Nationally: 46,200 additional deaths\(^1\)
- Additional ~9 days hospital LOS\(^2\)
- Additional > $53,000 to hospital costs\(^2\)
- 1/3 ‘Code Blue’ due to respiratory arrest\(^3\)

Respiratory Depression BEFORE Respiratory Failure
Definition of Respiratory Depression

- No standard definition
- Clinical
  - Bradypnea (RR 8-10)
  - Sedation (Richmond-Agitation Sedation Score)
  - Opioid antagonist administration
- Monitoring
  - Arterial blood gas
  - Hypoxemia ($\text{SpO}_2 < 85-90\%, \text{ duration } 30\text{s}-2\text{min})$
  - Hypercapnia ($\geq 50\text{mmHg or trend}$)

Risk of Respiratory Depression
Postoperative Setting

- Incidence of critical respiratory events in the PACU between 0.8% and 6.9% \(^1\)
- Incidence of respiratory depression 0.5-2% among post-operative patients (due to opioids) \(^2\)

Severity of the Problem Postoperative Opioids

The Joint Commission’s Opioid Related Sentinel Event Database (2004-2011)¹

- 47% wrong dose medication errors
- 29% related to improper monitoring of the patient
- 11% to other factors (i.e. excessive dosing, medication interactions, adverse drug reactions)

Anesthesia Closed Claims Database²

- 97% of opioid related respiratory events were deemed preventable with better monitoring

1) https://www.jointcommission.org/assets/1/18/SEA_49_opioids_8_2_12_final.pdf
2) Lee LA et al. Postoperative Opioid-Induced Respiratory Depression. Anesthesiology 2015; 122: 659-65
Monitoring Choices

- Clinical (intermittent nursing checks)
  - Bradypnea (RR 8-10)
  - Sedation (Richmond-Agitation Sedation Score)
- Monitoring (intermittent or continuous)
  - Arterial blood gas
  - Impedance plethysmography
  - Pulse Oximetry- Hypoxemia ($\text{SpO}_2 < 85\text{-}90\%$, duration 30s-2min)
  - End tidal $\text{CO}_2$/Transcutaneous $\text{CO}_2$- Hypercapnia ($\geq 50\text{mmHg}$ or trend)
Timing of Respiratory Depression

60% ‘SOMNOLENT’ prior to event

Fig. 1. Time between last nursing check and discovery of opioid-induced respiratory depression (RD). Claims with unknown timing (n = 39) and not applicable (at home, n = 3) not shown.

Timing of Respiratory Depression

- Observational study
- N= 833
- Noncardiac surgery
  - CPOX
  - q4-6 hour nursing spot-check for desaturation
- Overall 21% had average of >10 min/h SpO2<90%
- BUT 37% of cohort had SpO2<90% for over an hour

Respiratory Depression on Oxygen

\[ \text{PAO2} = (PB - PH2O) \text{FiO2} - (\text{PaCO2} \div R) \]

Pulse Oximetry and CO$_2$ Monitoring

- Continuous pulse oximetry inconclusive whether reduces rapid response team calls or mortality, trend toward reducing ICU transfers
- Continuous pulse oximetry is 15X more likely to detect RD than nursing checks
- Capnography is 6X more likely to detect RD than pulse oximetry
- Clear that we should be monitoring oxygenation and ventilation

Respiratory depression is ...."Potentially preventable with improvements in monitoring of ventilation, and early response and intervention, particularly within the first 24 hours postoperatively."

"The Task Force emphasizes that because ventilation and oxygenation are separate though related physiologic processes, monitoring oxygenation by pulse oximetry is not a substitute for monitoring ventilatory function."
### Table 2. Medication Factors Associated with Respiratory Depression

<table>
<thead>
<tr>
<th>Route of Opioid Therapy</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCA only</td>
<td>17 (18)</td>
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<tr>
<td>Neuraxial only</td>
<td>16 (17)</td>
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<tr>
<td>Other only*</td>
<td>16 (17)</td>
</tr>
<tr>
<td>Multimodal*</td>
<td>43 (47)</td>
</tr>
</tbody>
</table>

- Continuous infusion of opioids: 42 (46)
- Interaction of opioid and nonopioid sedative medications: 31 (34)
- More than one physician prescribing (n = 91): 30 (33)
- Excessive opioid dose: 15 (16)
Recommendations for Detection and Monitoring for Respiratory Depression

- Monitor all patients receiving neuraxial opioids for adequacy of ventilation (e.g., respiratory rate, depth of respiration [assessed without disturbing a sleeping patient]), oxygenation (e.g., pulse oximetry when appropriate), and level of consciousness.**
- Increased monitoring (e.g., intensity, duration, or additional methods of monitoring) may be warranted for patients at increased risk of respiratory depression (e.g., unstable medical condition, obesity, obstructive sleep apnea,†† concomitant administration of opioid analgesics or hypnotics by other routes, extremes of age).
Carbon dioxide monitoring is required based upon the level of sedation, moderate or deep, and is irrespective of the location or type of anesthesia used. We would make an argument that a similar degree of monitoring should be maintained in the postoperative environment where most patients are still in a sedated state, especially in patients at high-risk for respiratory compromise.

Capnography or other monitoring modalities that measure the adequacy of ventilation and airflow is indicated when supplemental oxygen is needed to maintain acceptable oxygen saturations.

Monitoring continuous oxygenation and ventilation from a central location (telemetry or comparable technologies) is desirable. This information needs to be reliably transmitted to the healthcare professional caring for the patient at the bedside.
• Recommendation: Create and implement policies and procedures for the ongoing clinical monitoring of patients receiving opioid therapy by performing serial assessments of the quality and adequacy of respiration... Staff should be educated not to rely on pulse oximetry alone.... especially when supplemental oxygen is being used.

https://www.jointcommission.org/assets/1/18/SEA_49_opioids_8_2_12_final.pdf
Challenge 4 | Failure to Rescue: Monitoring Opioid-Induced Respiratory Depression

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- DOWNLOAD THE FREE APSS AT PATIENTSAFETYMOVEMENT.ORG/APSS

“As a result of the changes, Baylor University Medical Center went from 40 monthly rapid response team activations a month to 3, and these are early calls! Due to the continuous monitoring of patients, staff are warned early enough to identify and treat patients, preventing costly return to ICU stays. It has saved the hospital money and more importantly kept patients’ safe.”

Dr. Michael A.E. Ramsay MD, FRCA Chairman, Department of Anesthesiology and Pain Management at Baylor University Medical Center
When pulse oximetry or capnography is used, it should be used continuously rather than intermittently.
## Monitoring Guidelines

<table>
<thead>
<tr>
<th>Organization</th>
<th>ASA</th>
<th>APSF</th>
<th>ASPMN</th>
<th>JC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous SpO2 for patient at risk for RC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Continuous capnography for patients at risk for RC</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Continuous monitoring by telemetry may be used</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
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ASA = American Society of Anesthesiologists  
APSF = Anesthesia Patient Safety Foundation  
ASPMN = American Society for Pain Management Nursing  
JC = Joint Commission
Risk Factors for Respiratory Depression

- Obstructive Sleep Apnea
- Morbid Obesity (BMI ≥ 40kg/m²)
- Snoring
- Age
- Opioid Naive
- Post Surgery
- General Anesthesia
- Cardiac/Pulmonary Co-morbidities
- Concomitant Sedating Drugs
- Smoker
Validated OSA Questionnaire’s

STOP-BANG Sleep Apnea Questionnaire

<table>
<thead>
<tr>
<th>STOP</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you SNORE loudly (louder than talking or loud enough to be heard through closed doors)?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Do you often feel TIRED, fatigued, or sleepy during daytime?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Has anyone OBSERVED you stop breathing during your sleep?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Do you have or are you being treated for high blood PRESSURE?</td>
<td>Yes</td>
<td>No</td>
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<tr>
<th>BANG</th>
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<tr>
<td>BMI more than 35 kg/m²?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>ACE over 50 years old?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>NECK circumference &gt; 16 inches (40 cm)?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>GENDER: Male?</td>
<td>Yes</td>
<td>No</td>
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TOTAL SCORE

High risk of OSA: Yes 8 - 8
Intermediate risk of OSA: Yes 3 - 4
Low risk of OSA: Yes 0 - 2
## Perioperative Risk Factors for Respiratory Depression

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*Opioid via multiple routes*

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<tr>
<th>Continuous Pulse Oximetry Monitoring</th>
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Table 4. Advantages and Disadvantages of Continuous Pulse Oximetry and Continuous Capnography Monitoring

Transcutaneous CO₂ Monitor

Capnography Waveform Interpretation

by Chris Nickson, Last updated May 24, 2016

OVERVIEW

- Capnography waveform interpretation can be used for diagnosis and ventilator-trouble shooting
- The CO2 waveform can be analyzed for 5 characteristics:
  - Height
  - Frequency
  - Rhythm
  - Baseline
  - Shape

5 things to know about capnography

Understand the importance of monitoring end-tidal carbon dioxide and the valuable information it provides for patient assessment and treatment

Apr 27, 2015
- Arterial CO$_2$ can rise without a rise in EtCO$_2$
- BOTH
  - Physiologic dead space = (PaCO$_2$ - PexpCO$_2$) / PaCO$_2$
    - % Tidal volume not contributing to gas exchange
    - Ventilated but underperfused parts of the lung
- Shunt (has to be >50% to contribute to hypercapnia)
  - Perfused but underventilated

Multiple Settings Where End Tidal CO₂ Monitoring is not Accurate

- Increased dead space ventilation
  Yamanaka MK et al, Chest 1987;92:832

- Critically ill adult ICU patients
  Hoffman RA et al, Amer Rev Resp Dis 1989;140:1265

- Intraoperative care
  Wahaba RWM et al, Can J Anaesth 1996;43:862

- One-lung ventilation
  Yam PCI et al, Br J Anaesth 1994;72:21

- Patient positioning
  Grenier B et al, Anesth Analg 1999;88:43

- Type of ventilator affects accuracy of ETCO2 monitoring
  Badgwell JM et al, Anesthesiology 1987;66:405
Transcutaneous CO\textsubscript{2} Monitoring: What is it?

- Continuous monitoring
- Central Monitoring compatible
- Transcutaneous CO\textsubscript{2}
- Pulse Oximetry
Transcutaneous CO$_2$ Monitoring: What is it?

- Stow-Severinghaus type electrode:
  - Heated sensor
- Measures pH ∆- converts to CO$_2$ reading
- Accuracy TcCO$_2$ within 0-6mmHg $^{1,2,3}$

Transcutaneous CO2 Monitoring: Accuracy

1 kPa = 7.5 mmHg


Transcutaneous CO2 Monitoring Sites

= multisite attachment ring
Transcutaneous CO2 Monitoring vs Capnography

- Easy, easy, easy
- Quantitative CO₂ measurement
- Independent of tidal volume
- Pulse oximetry built in
- Less patient aggravation
Transcutaneous CO₂ Monitoring is Accurate for ....

...Intrahospital transport of critically ill and ventilated adults


...One lung ventilation

Cox P & Tobias J. Noninvasive monitoring of PaCO₂ during one-lung ventilation and minimal access surgery in adults: End-tidal versus transcutaneous techniques 2007; 3:.


...Spontaneously breathing nonintubated ICU patients admitted for acute respiratory failure


.... Morbidly obese patients to detect perioperative hypercapnia


...Laparoscopic radical gastrectomy or radical proctectomy under general anesthesia

Transcutaneous CO2 Monitoring: Use in Perioperative Setting

- Monitor Sedation Cases
- Monitor General Anesthesia for ‘Nontraditional Cases’
  - High Frequency Jet Ventilation
  - High Frequency Oscillation
  - One Lung Ventilation
  - Prolonged apneic phases
- Monitor High Risk Patients
  - PACU
  - Risk Factors for Respiratory Depression
    - OSA, Obesity, Co-morbidities, etc.
  - Postoperative Surgical Floors
    - Systemic or neuraxial opioids
The safety and economic burden of respiratory failure is high in the perioperative setting.

Continuous pulse oximetry and respiratory monitoring can increase identification of respiratory depression and is recommended by multiple national organizations.

Patients should be screened for risk factors for respiratory depression and those at high risk should have continuous monitoring for both oxygenation and ventilation.

Transcutaneous carbon dioxide monitoring provides continuous oxygenation and ventilatory monitoring that is more convenient and for the patient and healthcare providers and more accurate than capnography.