Capnography - The most vital of vital signs

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Learning Outcomes

• State why capnography is considered the most important vital sign.

• Describe how capnography can prevent sentinel events due to over sedation.
Value of Different Assessment Tools

- Which assessment tools are the most helpful
- How to select patients for each assessment method
Improving Pulmonary Physical Assessment
Changing Face of Assessment

The NEW ENGLAND JOURNAL of MEDICINE

Perspective

Point-of-Care Ultrasound in Medical Education — Stop Listening and Look

Scott D. Solomon, M.D., and Fidencio Saldana, M.D.

In 1816, the French physician René-Théophile-Hyacinthe Laennec, inspired by children communicating by tapping a pin on one end of a long piece of wood and listening at the other end, rolled a “quire” of paper into a cylinder to listen to the heart of a sick young woman, instead of placing his ear directly on her bare chest. This improvised tool designed to protect a patient’s modesty evolved into the wooden instrument that eventually became the modern stethoscope. Nearly 200 years later, the stethoscope is unique among medical devices in that it is used by virtually every type of physician and, with the exception of electronic versions offering amplification and filtering, has changed minimally in style and technology. A fixture around the necks of physicians and medical students, it endures as an icon of our profession.

Yet during the past 50 years, diagnostic ultrasonography has replaced auscultation as the primary method of evaluating the mechanics of the heart and peering into the abdomen, vasculature, and
Apprehensions of New Medical Technologies

• In his preface to the English translation of Laennec's “A Treatise on the Diseases of the Chest and on Mediate Auscultation,” John Forbes wrote, “Notwithstanding its value, I am extremely doubtful, because its beneficial application requires much time, and gives a good deal of trouble both to the patient and the practitioner.”

• Any new technology requiring training and expertise is met with similar skepticism from practitioners steeped in older traditions.
Capnography: The Newest Vital Sign

- Has been called the 15-second triage tool
- The newest vital sign
- Its value lies in very simple application
  - Advanced use requires in depth understanding of ventilation and perfusion
How Capnography Reflects Ventilation and Perfusion

Normal Ventilation & Perfusion

Reduced blood flow decreases alveolar CO2. This decrease is detected in the exhaled breath by capnography.

Note: Increased blood flow to perfused alveoli is matched by increased ventilation to maintain PaCO₂ within normal limits.
Key Uses of Capnography

• If PetCO2 increases, ventilation is threatened and airway protection may be needed.
• If PetCO2 suddenly falls to zero, airway is lost, breathing may have stopped, or the sensor is malpositioned.
• If PetCO2 suddenly falls (without a change in Ve), the loss of cardiac output is likely.
Methods for Measuring Exhaled CO2 - Capnography

Hand held side stream capnogram

Bedside monitor mainstream capnogram
Handheld, Nasal Cannula
Capnography reflects CO2 when exhaled from the lungs

- At the end of exhalation, called the end tidal CO2 or PetCO2 for pressure of CO2 at end tidal breathing, the exhaled CO2 is reflecting alveolar CO2. Normally, the PetCO2 value is 1-5 mm Hg below the arterial (or alveolar) CO2 level.
Identifying Adequate CO2 Emptying Pattern

Incomplete exhaled CO2 pattern

Adequate plateau phase indicating good alveolar emptying
Clinical Application Assessing Adequacy of Ventilation

If PetCO2 increases, ventilation is threatened and airway protection may be needed.

A rise in the PetCO2 of > 5 mm Hg is abnormal. Action may be needed.

A rise in the PetCO2 of > 10 mm Hg needs support of breathing and/or reversal of analgesia/sedation.

Ventilation Assessment

• The main reason for a PetCO2 value to increase is reduced alveolar ventilation.
  – Obtaining a blood gas can confirm this possibility.
• During sedation, weaning from ventilation or managing reactive airway patients, the PetCO2 is the first indication of danger.
  – If the PetCO2 increases by 10 mm Hg, airway protection should be implemented.
  – If sedation or analgesia is being administered, stop the infusion until the PetCO2 returns to near baseline.
  • Monitoring patient simultaneously for comfort and awareness.
Limited Role of Pulse Oximetry in Assessing Ventilation

• Normal SaO2 determined by PaO2
• If patient hypoventilates, PaCO2 increases and will drive PaO2 downward in direct proportion to PaCO2 increase
  – If PaCO2 increases by 10, PaO2 will decrease by 10
  – If PaO2 is 90, will decrease to 80 mm Hg
    • SaO2 will decrease from 98 to 97.
• Oximeter is not sensitive to rises in PaCO2
• When oxygen therapy is added or increased, rise in PaCO2 is completely obscured
### Case Example of Limited Role of Oximetry in Hypoventilation

<table>
<thead>
<tr>
<th></th>
<th>1st Value</th>
<th>2nd Value</th>
<th>3rd Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO2</td>
<td>95</td>
<td>80</td>
<td>99</td>
</tr>
<tr>
<td>SpO2</td>
<td>.98</td>
<td>.96</td>
<td>.98</td>
</tr>
<tr>
<td>FIO2</td>
<td>RA</td>
<td>RA</td>
<td>.30</td>
</tr>
<tr>
<td>PetCO2</td>
<td>39</td>
<td>54</td>
<td>60</td>
</tr>
<tr>
<td>pH</td>
<td>7.38</td>
<td>7.25</td>
<td>7.23</td>
</tr>
</tbody>
</table>
PetCO2 and Preventing Oversedation

Oversedation is the #2 cause of preventable drug harm.

2015 Percent

- Oversedation (n=223): 52%
- Hypoglycemia: 34%
- All Other: 14%

Opioids n= 199  Benzo n= 24
Capnography Monitoring During Conscious Sedation & Post Surgical Pain Management
Simple Capnography Guidelines for Monitoring Ventilation During Sedation or Analgesia

• If the PetCO2 does not increase by 5-10 mm Hg after sedation or analgesia is given, intervention is generally not necessary.
Ventilation Management With Capnography

• If the PetCO2 increases by more than 5-10 mm Hg, immediately evaluate the patient.

• If the patient is alert and oriented, observe for any changes in level of conscious.
  • If the patient has a change in LOC or behavior, hold further sedation or analgesia until the PetCO2 returns to near baseline values.

PetCO2 initially was 37, not 52
Ventilation Management With Capnography

- If the patient is unstable with an increase in the PetCO2 (e.g., unresponsive, with a RASS of -4 or -5, or hypotensive (SBP < 90 or MAP less than 60), call the rapid response team.
- The RRT will likely reverse the analgesia or sedation until the PetCO2 returns to baseline and the patient is alert and able to protect their airway (i.e., should have a good cough reflex).
Richmond Agitation and Sedation Scale (RASS)*

<table>
<thead>
<tr>
<th>Scale</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>COMBATIVE</td>
<td>Combative, violent, immediate danger to staff</td>
</tr>
<tr>
<td>+3</td>
<td>VERY AGITATED</td>
<td>Pulls to remove tubes or catheters; aggressive</td>
</tr>
<tr>
<td>+2</td>
<td>AGITATED</td>
<td>Frequent non-purposeful movement, fights ventilator</td>
</tr>
<tr>
<td>+1</td>
<td>RESTLESS</td>
<td>Anxious, apprehensive, movements not aggressive</td>
</tr>
<tr>
<td>0</td>
<td>ALERT &amp; CALM</td>
<td>Spontaneously pays attention to caregiver</td>
</tr>
<tr>
<td>-1</td>
<td>DROWSY</td>
<td>Not fully alert, but has sustained awakening to voice (eye opening &amp; contact &gt;10 sec)</td>
</tr>
<tr>
<td>-2</td>
<td>LIGHT SEDATION</td>
<td>Briefly awakens to voice (eyes open &amp; contact &lt;10 sec)</td>
</tr>
<tr>
<td>-3</td>
<td>MODERATE SEDATION</td>
<td>Movement or eye opening to voice (no eye contact)</td>
</tr>
</tbody>
</table>

If RASS is ≥ -3 proceed to CAM-ICU (Is patient CAM-ICU positive or negative?)

-4    | DEEP SEDATION          | No response to voice, but movement or eye opening to physical stimulation   |
-5    | UNAROUSABLE            | No response to voice or physical stimulation                                |

If RASS is -4 or -5 → STOP (patient unconscious), RECHECK later

Ely, et al., JAMA 2003; 286, 2983-2991

*Useful for determining the degree of patient sedation
Reversing Sedation and Analgesia

• If the patient is stable, pause the medication.
• If the patient is unstable, reverse the medication.
  • To reverse sedation from a benzodiazepem, give Flumazenil (Romazicon) IV or IM.
  • To reverse an opioid, administer Naloxone (Narcan) – IV.
    • Dahan A, Aarts L, Smith TW. Incidence, reversal and prevention of opioid induced respiration depression. Anesthesiology 2010 Jan;112(1):226-38
• Administer only small amounts of the reversal agent to prevent too rapid of a reversal.
Question

Example 1 – Conscious Sedation

A 56 year old man admitted to the outpatient procedure area for a follow-up colonoscopy. The patient had a colonoscopy 3 years earlier where a precancerous polyp was removed. Five minutes into the procedure, you note the PetCO2 listed below.

What would your actions be based on this information?

<table>
<thead>
<tr>
<th></th>
<th>HR</th>
<th>RR</th>
<th>BP</th>
<th>SpO2</th>
<th>PetCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admission</td>
<td>82</td>
<td>14</td>
<td>142/84</td>
<td>96</td>
<td>32</td>
</tr>
<tr>
<td>3 minutes after sedation</td>
<td>74</td>
<td>11</td>
<td>130/78</td>
<td>95</td>
<td>39</td>
</tr>
<tr>
<td>5 minutes after sedation</td>
<td>74</td>
<td>11</td>
<td>132/80</td>
<td>94</td>
<td>44</td>
</tr>
</tbody>
</table>
The sedation should be paused to allow the PetCO2 to return to less than 37 mm Hg. Notice that no other parameters indicated a dangerous problem.

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</table>
A 59 year old male is post op and has a PCA device for pain management. He has given himself two doses of 1 mg of morphine.

Do you need to intervene?

<table>
<thead>
<tr>
<th>Time</th>
<th>P</th>
<th>RR</th>
<th>BP</th>
<th>SpO2</th>
<th>PetCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0730 (last self administered PCA dose)</td>
<td>80</td>
<td>13</td>
<td>118/76</td>
<td>99</td>
<td>32</td>
</tr>
<tr>
<td>0745</td>
<td>82</td>
<td>15</td>
<td>122/78</td>
<td>98</td>
<td>51</td>
</tr>
</tbody>
</table>
**Answer**

**Example 2 – Analgesia**

Yes. The patient should be evaluated and be locked out from further analgesia doses until the PetCO2 returns to less than 42. He is not unstable since his BP is adequate.

<table>
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<td>51</td>
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</table>
67 year old male 1 day post op for a nephrectomy. Has been given 3 mg of morphine for pain. When you check on him 15 minutes later, he is unable to be awakened by verbal stimuli. His RASS is -4. What should be your course of action?

<table>
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<tr>
<th>Time</th>
<th>P</th>
<th>RR</th>
<th>BP</th>
<th>SpO2</th>
<th>PetCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1315</td>
<td>83</td>
<td>15</td>
<td>112/74</td>
<td>99</td>
<td>41</td>
</tr>
<tr>
<td>1330</td>
<td>73</td>
<td>11</td>
<td>79/48</td>
<td>95</td>
<td>58</td>
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</table>
The morphine should be reversed with Naloxone. A rapid response call should be made to aid your efforts. The patient is unstable by both the RASS score and his low BP.

<table>
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<td>1330</td>
<td>73</td>
<td>11</td>
<td>79/48</td>
<td>95</td>
<td>58</td>
</tr>
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</table>
Technical Issues - Alarm Limits

- Alarms can be problematic if not set properly.
- Capnography upper limit alarm values should be set about 10 mm Hg above baseline PetCO2 values.
  - If no baseline is clear, a default setting of 50 or 60 mm Hg can be used.
- Lower alarm limits should be set between 10-20 mm Hg.
Respiratory Rate Alarms

• Respiratory rate alarms may or may not be used. If respiratory rate alarms are used, a setting of 4-6 can be selected.
  – Respiratory rate alarms are less helpful when capnography is utilized.
  – If a respiratory rate is too low to produce adequate ventilation, the capnogram value will be increasing.
Technology Issues - Alarm Prevention

• The most important way to prevent false alarms is to use proper patient selection.
  – Capnography is best used on patients who are not sedated or receiving opioid analgesics.
  – Patients who are awake and actively moving their head are not good candidates for capnography.
  – Patients who are ambulatory are not likely good candidates for capnography.
Technical Issues

Improper cannula placement can cause alarms and inaccurate readings.

Proper cannula placement

Improper cannula placement
Legal Implications - Case Study 1

- A 44 yr old male admitted to MICU with unknown fever, SOB, hypoxemia. pH 7.34, PaCO2 38, PaO2 44, SpO2 .78. He is intubated, IMV 12/44. Extubates himself; is reintubated. Sedation is increased. RR decreases to 12/12. He is now calm with a RASS of -4.

What is your action?
Legal Implications - Case Study 2

Physician notified a change in PetCO2. States to not worry about it since it is probably inaccurate.

What should you do?

<table>
<thead>
<tr>
<th></th>
<th>Pulse</th>
<th>RR</th>
<th>NIBP</th>
<th>SpO2</th>
<th>PetCO2</th>
<th>RASS</th>
<th>Meds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre PCA bolus</td>
<td>114</td>
<td>33</td>
<td>182/104</td>
<td>98</td>
<td>34</td>
<td>+2</td>
<td>2 mg Midazolam, 25 mcg/Fentanyl</td>
</tr>
<tr>
<td>Post PCA bolus</td>
<td>76</td>
<td>14</td>
<td>128/84</td>
<td>99</td>
<td>47</td>
<td>-3</td>
<td>Gtt to 75 mcg/Fentanyl via 2, 25 mcg bolus</td>
</tr>
</tbody>
</table>

[Table of vital signs and medications]
Summary

• Capnography can help identify patients at risk for respiratory compromise.
• Oximetry is useful but can remain normal even with respiratory depression.
• Physical assessment often provides late information regarding respiratory depression.
• Capnography can help in preventing sentinel events due to over sedation