## RESPIRATORY COMPROMISE AND CAPNOGRAPHY

WWW.PROMISETOAMANDA.ORG/AMANDAS-STORY/

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## RESPIRATORY COMPROMISE[1]

"Respiratory Compromise (RC) is a potentially life threatening state of unstable respiratory health: It is a gradual, subtle imbalance in patient response that encompasses respiratory failure and arrest, with symptoms that manifest differently in each patient."

- Respiratory Compromise Institute
www.respiratorycompromise.org

RCI
RESPIRATORY COMPROMISE INSTITUTE



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## RESPIRATORY COMPROMISE CATCHING THE CASCADE

01 *At Risk*
Patient Desaturates

02 *Respiratory Insufficiency*
2LPM NC, continues to desaturate
4 LPM NC, continues to desaturate

03 *Respiratory Failure*
6LPM NC, continues to desaturate
NRB applied

04 *Respiratory Arrest*
Patient 'resting comfortably' in nurses notes

05 Airway/Vent Support Needed. Could be found "Dead in Bed"

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## RESPIRATORY COMPROMISE BY THE NUMBERS

**SECOND** leading avoidable patient safety issue

**THIRD** most common cause of avoidable deaths in the U.S. *(estimated 300,000-400,000 per year)*

**THIRD** most rapidly increasing hospital inpatient cost in the US

**FIFTH** top condition leading to increasing hospital costs[1]

Risk of death is **29%** higher among patients with respiratory compromise

Common.

Costly.

Deadly.

**Preventable.**

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## CAPNOGRAPHY



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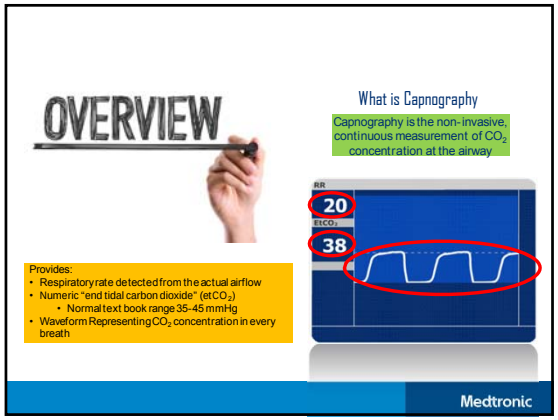
OVERVIEW
What is Capnography
Capnography is the non-invasive, continuous measurement of $CO_2$ concentration at the airway
Provides:
• Respiratory rate detected from the actual airflow
• Numeric "end tidal carbon dioxide" ($etCO_2$)
• Normal text book range 35-45 mmHg
• Waveform Representing $CO_2$ concentration in every breath
RR
20
ETCO2
38
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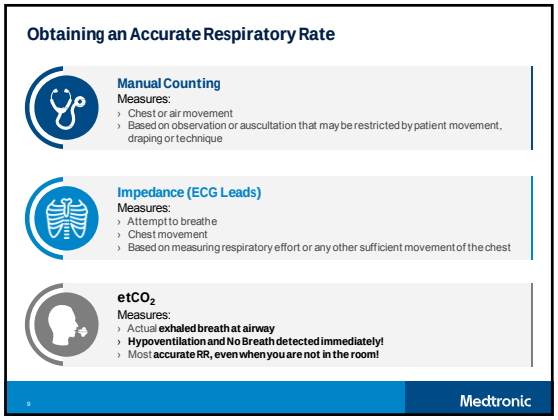
Obtaining an Accurate Respiratory Rate
Manual Counting
Measures:
› Chest or air movement
› Based on observation or auscultation that may be restricted by patient movement, draping or technique
Impedance (ECG Leads)
Measures:
› Attempt to breathe
› Chest movement
› Based on measuring respiratory effort or any other sufficient movement of the chest
$etCO_2$
Measures:
› Actual exhaled breath at airway
› Hypoventilation and No Breath detected immediately!
› Most accurate RR, even when you are not in the room!
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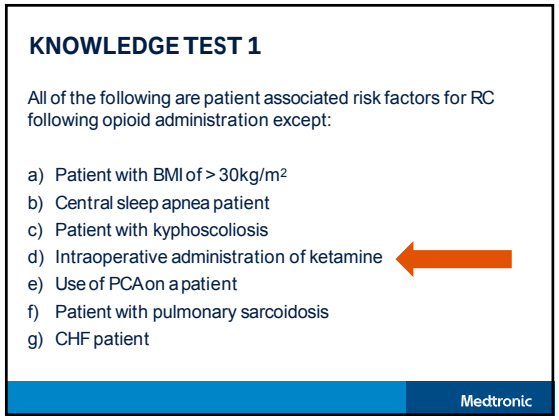
KNOWLEDGE TEST 1
All of the following are patient associated risk factors for RC following opioid administration except:
a) Patient with BMI of > 30kg/m²
b) Central sleep apnea patient
c) Patient with kyphoscoliosis
d) Intraoperative administration of ketamine
e) Use of PCA on a patient
f) Patient with pulmonary sarcoidosis
g) CHF patient
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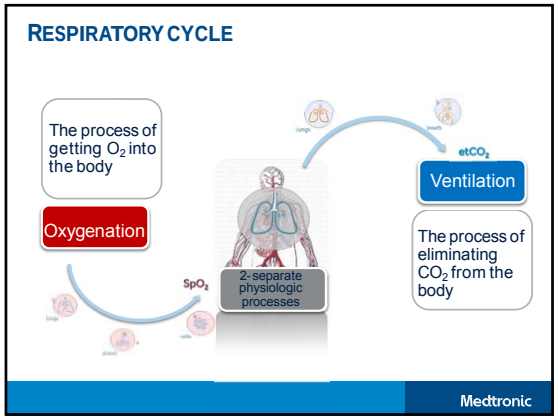
RESPIRATORY CYCLE
The process of getting $O_2$ into the body
Oxygenation
Ventilation
The process of eliminating $CO_2$ from the body
$SpO_2$
$etCO_2$
2-separate physiologic processes
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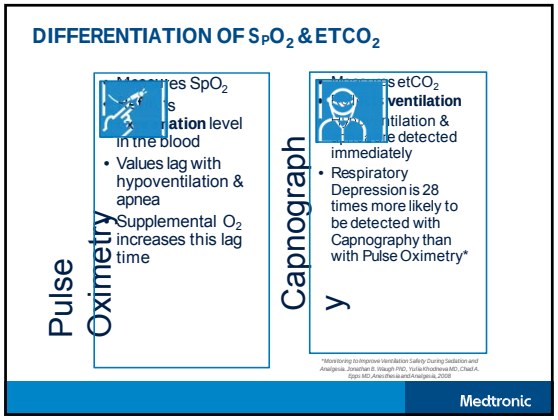
DIFFERENTIATION OF $SpO_2$ & $ETCO_2$
Pulse Oximetry
Measures $SpO_2$
ration level in the blood
• Values lag with hypoventilation & apnea
• Supplemental $O_2$ increases this lag time
Capnography
ventilation
• Respiratory Depression is 28 times more likely to be detected with Capnography than with Pulse Oximetry*
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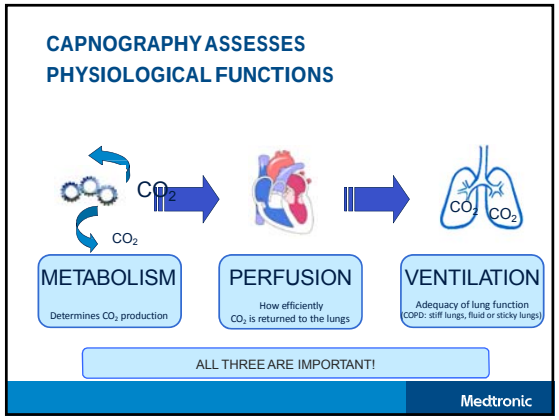
CAPNOGRAPHY ASSESSES PHYSIOLOGICAL FUNCTIONS
$CO_2$
$CO_2$
$CO_2$
$CO_2$
METABOLISM
Determines $CO_2$ production
PERFUSION
How efficiently $CO_2$ is returned to the lungs
VENTILATION
Adequacy of lung function
COPD: stiff lungs, fluid or sticky lungs)
ALL THREE ARE IMPORTANT!
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## FACTORS THAT INCREASE ETCO2

| Metabolic | Perfusion | Ventilation | Technical Errors |
|---|---|---|---|
| Fever<br>Malignant hyperpyrexia<br>Sodium bicarbonate<br>Tourniquet release<br>Venous $CO_2$ embolism | Increased cardiac output<br>Increased blood pressure<br>ROSC<br>Effective chest compressions | Bronchial intubation<br>Partial airway obstruction<br>Rebreathing (expiratory time too short)<br>Hypoventilation w/sedation<br>RR or Vt is too low on ventilator | Exhausted $CO_2$ absorber<br>Inadequate fresh gas flows<br>Leaks in breathing system<br>Faulty ventilator<br>Faulty valves |

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## FACTORS THAT DECREASE ETCO2

| Metabolic | Perfusion | Ventilation | Technical Errors |
|---|---|---|---|
| Hypothermia<br>NPO | Reduced cardiac output<br>Hypotension<br>Hypovolemia<br>Pulmonary embolism Cardiac arrest | Shallow breathing<br>Hyperventilation<br>Apnea<br>Total/Partial airway obstruction<br>Tracheal extubation<br>V/Q mismatch or Shunting/ARDS<br>RR or Vt too high on MV | Circuit disconnection<br>Sampling tube leak or kinked ET tube<br>Malfunction of ventilator |

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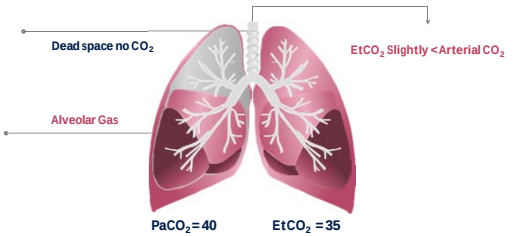
## RELATIONSHIP BETWEEN $PACO_2$ & $PETCO_2$ V/Q MISMATCH




| $PaCO_2$ Vs $EtCO_2$ Values: | 35-45mmHg *(Normal ABG)* | 2-5mmHg difference between ABG and $EtCO_2$ *(in healthy adults)* | 0-3mmHg difference between ABG and $EtCO_2$ *(in neonates)* |
|---|---|---|---|

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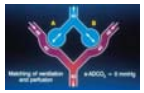
## VENTILATION & PERFUSION MATCHING

**Normal Shunt Perfusion**

- Physiologic Dead Space
- Normal Physiologic Shunt



(a-Et)PCO2 = 2-5mmHg

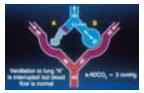
**Deadspace Ventilation**

- Ventilation - No Perfusion
- EtCO2 < PaCO2

- Pulmonary embolism
- Cardiac arrest
- Hypovolemia
- Hypoxic Pulmonary
- Vasoconstriction

**Abnormal Shunt Perfusion**

- Perfusion – No Ventilation
- EtCO2 < PaCO2



- Pulmonary Edema
- Pneumonia
- ALI/ARDS
- Bronchial Intubation
- Mucus Plugging
- Bronchospasm
- Severe Atelectasis

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**Name:** Leah Coufal

**Age:** 11

**Diagnosis:** Pectus carinatum repair

*"Would real- time monitoring have saved Leah? That is one of the many questions that I have asked myself every day since I found my daughter, Leah, dead in her hospital bed. The answer is yes, it would have." -Lenore Alexander*

http://www.goals.org/2012/02/guest-post-yes-real-time-monitoring-would-have-saved-leah-/ (http://www.leahslegacy.org/leahs-story/

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## MANY CONDITIONS MAY CAUSE RESPIRATORY FAILURE...

**Questions/Complexity arise**

- What do I monitor COPD vs pneumonia vs postop vs HF vs...?
- How does monitoring guide intervention?


MacIntyre N. **Pathophysiology of Respiratory Compromise. Respiratory Compromise Roundtable, Orlando, FL. Feb 2014** http://www.respiratorycompromise.org/wp-content/uploads/2013/12/Pathophysiology-of-Respiratory-Compromise.pdf

Graphic from Lynn LA, Curry JP. Patterns of unexpected in-hospital deaths: a root cause analysis. Safety in Surgery 2011, 5:3 (epub) http://www.pssjournal.com/content/5/1/3

19 Presentation Title (Edit on Slide Master) | June 1, 2015 | Confidential, for Internal Use Only

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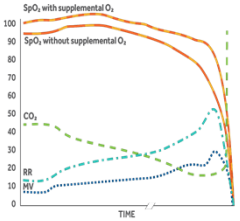
## HYPOXEMIC RESPIRATORY FAILURE (TYPE I)
### OXYGENATION FAILURE

- **Primary Issue** – Decreasing ability to oxygenate blood due to congestion (e.g., fluid, pus, etc.) in lung tissue (alveoli)
- **Examples** – Pneumonia, ARDS, sepsis, HF, etc
- **Monitor Trend Results**
  - $S_aO_2$ is maintained above 90% through a significant drop in arterial oxygen ($P_aO_2$) due to:
  - To compensate, patient breathes faster and/or deeper increasing minute volume (MV) and clinicians give supplemental $O_2$
  - Decreasing blood $CO_2$ ($PaCO_2$ or $etCO_2$)
- **Interventions** - Aimed at clearing congestion and improving oxygenation (FRC)




Graphs adapted from: Lynn LA, Curry JP. Patterns of unexpected in-hospital deaths: a root cause analysis. Safety in Surgery 2011, 5:3 (epub)
http://www.pssjournal.com/content/5/1/3

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## EXAMPLE OF HYPOXEMIC RESPIRATORY FAILURE (TYPE I)
### OXYGENATION FAILURE

*"A healthy male who had just undergone elective surgery develops shortness of breath that's noticed by his family who express concern to the nurse. The nurse, citing a normal oxygen saturation reading on his oximeter, reassures the family that the monitor indicates he's okay. Eventually his respiratory rate does rise to a critical value, but by this time it's too late to effectively respond to his rapidly deteriorating clinical condition and the patient, with sepsis, dies."*

Curry and Jungquist Patient Safety in Surgery 2014, 8:29
http://www.pssjournal.com/content/8/1/29

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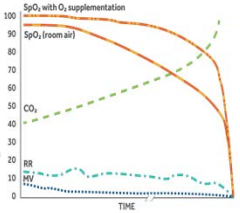
## HYPERCAPNIC RESPIRATORY FAILURE (TYPE II)
### VENTILATION FAILURE

- **Primary Issue**: Inadequate ventilation to clear carbon dioxide – Hypoventilation
  - Decreased RR and/or tidal volume = decreased minute volume (MV). RR can be normal and MV is decreasing as a result of shallow breathing
- **Examples** – Opioid use, sedation, brain injury, obesity hypoventilation syndrome, etc.
- **Monitor Trend Results**
  - $S_aO_2$ is maintained above 90% through a significant rise in $CO_2$.
  - Normal, decreasing, or increasing RR
  - Increasing $CO_2$ (ABG or $etCO_2$)
- **Interventions** aimed at improving ventilation
  - Airway maneuvers
  - Reducing respiratory depression
  - Ventilatory support




Graphs adapted from: Lynn LA, Curry JP. Patterns of unexpected in-hospital deaths: a root cause analysis. Safety in Surgery 2011, 5:3 (epub)
http://www.pssjournal.com/content/5/1/3

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## EXAMPLE OF HYPERCAPNIC FAILURE (TYPE II)
### VENTILATORY FAILURE

*"A healthy female who is receiving routine post–op nasal oxygen has been up all night complaining of severe postop pain, but is now finally asleep after yet another dose of IV opioid. The nurse, noticing on rounds the patient's oxygen saturation is 'perfect' on the monitor, decides not to awaken her. She is found dead in bed 4 hours later."*

Curry and Jungquist Patient Safety in Surgery 2014, 8:29
http://www.pssjournal.com/content/8/1/29

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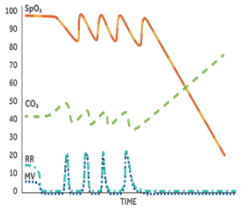
## AROUSAL FAILURE (TYPE III)
### SLEEP DISORDERED BREATHING

- **Primary Issue** – Recurring apneas and/or shallow breathing during sleep
  - Repetitive pattern of hypoventilation followed by hyperventilation
  - Normal protective mechanism is to 'arouse' when $O_2$/$CO_2$ levels are abnormal
  - Recovery response may be blunted by opioids, sedatives, alcohol, etc.
- **Examples** – Obstructive sleep apnea, central sleep apnea, Cheyne-Stokes Resp
- **Monitor Results**
  - Sawtooth pattern of drops and increases in RR, MV, $SpO_2$ with reciprocal change in $CO_2$
- **Interventions** Undx SDB management
  - Screening tools
  - Positive Airway Pressure therapies
  - Judicious use of arousal/RD suppressants




Graphs adapted from: Lynn LA, Curry JP. Patterns of unexpected in-hospital deaths: a root cause analysis. Safety in Surgery 2011, 5:3 (epub)
http://www.pssjournal.com/content/5/1/3

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## EXAMPLE OF AROUSAL FAILURE (TYPE III)
### AROUSAL FAILURE

*"An otherwise healthy male with unrecognized sleep apnea receives a post-operative opioid. His alarm sounds repeatedly but lasts only for about 30 seconds before it stops, only to repeat again and again. When the nurse awakens the patient he feels fine and is completely alert, asking for more pain medication, which the nurse gives in a normal dose. The nurse, suffering from alarm fatigue, stops responding to the same alarming. Later that night the patient is found dead in bed."*

Curry and Jungquist Patient Safety in Surgery 2014, 8:29
http://www.pssjournal.com/content/8/1/29

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## KNOWLEDGE TEST 2

Hypercapnia can occur with normal $SpO_2$?

a) YES
b) NO

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Capnography Waveform 101

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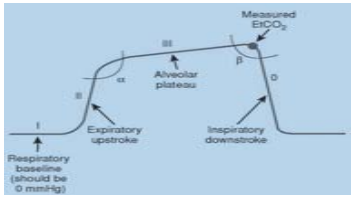
## NORMAL CAPNOGRAPHIC WAVEFORM




**I:** Baseline = no $CO_2$ in breath
**II:** Rapid rise in $CO_2$ (clearing dead space)
**III:** Alveolar plateau (gas exchange)
**IV:** End expiration ($etCO_2$ measured)
**V:** Inhalation

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## NORMAL WAVEFORM


$SpO_2$ – Normal
$EtCO_2$ - Normal Range 35-45
Waveform – Normal
RR – Normal

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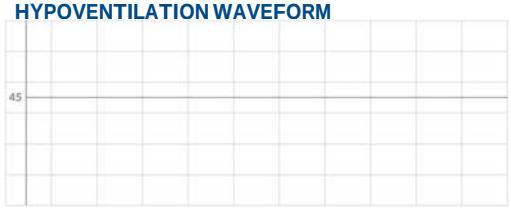
## HYPOVENTILATION WAVEFORM




$SpO_2$ – Normal
$EtCO_2$ – Increased
Waveform – increased in amplitude and width
RR – very decreased

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## HYPERVENTILATION WAVEFORM


$SpO_2$ – Normal
$EtCO_2$ – decreasing
Waveform – decreasing in amplitude and width
RR – increased

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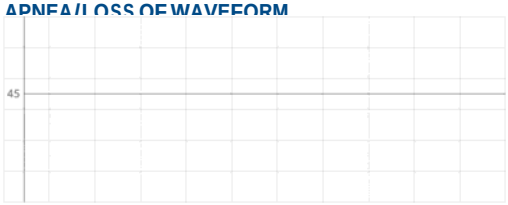
## APNEA / LOSS OF WAVEFORM




$SpO_2$ – Normal or sudden decrease noted
$EtCO_2$ – Zero
Waveform – Absent
RR – Zero
Other – no chest wall movement or breath sounds noted

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## AIRWAY OBSTRUCTION


Absent alveolar plateau indicates incomplete alveolar emptying or loss of airway integrity.
-Tongue or position of head
-Secretions
-Talking or snoring

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## SHALLOW BREATHING


Hypoventilation with shallow respirations

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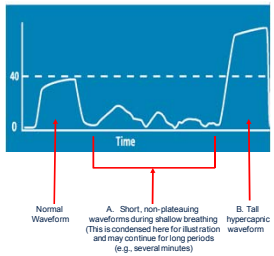
## HYPOPNEIC HYPOVENTILATION (SHALLOW BREATHING)
A MOST MISUNDERSTOOD WAVEFORM

- During very shallow breathing, the waveforms **don't** reach the alveolar plateau (see waveforms A)
- These short, incomplete waveforms can continue for extended periods (several minutes) **causing a build up of $CO_2$ in the blood while et$CO_2$ is reading low**
- Eventually, the patient does take a normal sized breath with an alveolar plateau (B in graphic), the et$CO_2$ reading will be high and waveform will be tall. **The extent of hypercapnia will depend on the length and severity of the shallow breathing.**
- **FYI**: The period of shallow breathing would have to be much longer than just a few breaths to show a low et$CO_2$ reading and result in hypercapnia.

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## KNOWLEDGE TEST 3

Cases of respiratory depression are _____times as likely to be detected, if they are monitored with capnography, as those who were not monitored.

a) 5
b) 17
c) 28
d) 36

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## ABNORMAL WAVEFORM - WHAT TO DO
NON-INTUBATED PATIENT

01 Assess Patient
02 Check FilterLine® position – reposition as necessary
03 Check patient's head and neck position – reposition as necessary
04 Periodically instruct patient to take a deep breath as necessary
05 If patient is "not breathing" Follow protocol (ABC's) $CO_2$

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## What Do The Alarms Mean?

| Does the Patient have: | Clinical Assessment Considerations: |
|---|---|
| › Low RR alarms<br>› Decreasing RR | › Hypoventilation<br>› Shallow breathing<br>› Periods of "No Breath" or Apnea<br>› Check if $etCO_2$ level is increasing |
| › High $etCO_2$ alarm<br>› Increasing $etCO_2$ | › $CO_2$ accumulating<br>› Low RR<br>› Recent ingestion of carbonated beverages/antacids |
| › Low $etCO_2$ alarm<br>› Decreasing $etCO_2$ | › RR increasing/hyperventilating<br>› Shallow breathing |
| No Breath or Apnea alarm | › Apnea<br>› Complete airway obstruction<br>› FilterLine needs repositioning<br>› Extreme shallow breathing |

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## POSSIBLE CLINICAL INTERVENTION

| | |
|---|---|
| Ensure an open airway | Allows ventilation, thus the removal of $CO_2$ |
| Stimulate your patient to take deep breaths | Removes $CO_2$ |
| Reposition FilterLine® if necessary | Provides accurate sample |
| Follow your policy | Know when to assist ventilation or withhold PCA medications |

*Remember: CO2 removal must keep-up with production!*

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## SOME KEYS TO SUCCESS

Educate the patient and family before you begin- get buy- in.

- What: "This FilterLine will help monitor your breathing".
- Why: "Your medication may slow your breathing. The cannula allows us to monitor your breathing even when I am not here. If you hear a beep, it is a reminder to take a breath".

It is all about patient safety!

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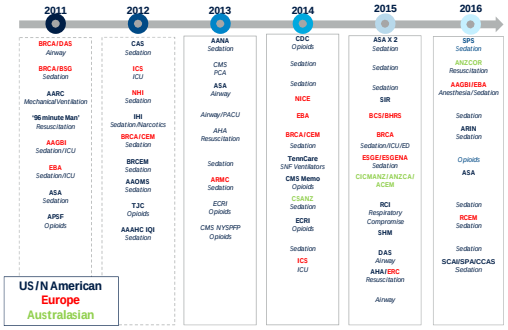
## GROWING WAVE OF CAPNOGRAPHY

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## 2010 AHA GUIDELINES FOR CARDIOPULMONARY RESUSCITATION AND EMERGENCY CARDIOVASCULAR CARE SCIENCE

"Continuous waveform capnography is recommended in addition to clinical assessment as the most reliable method of confirming and monitoring correct placement of an endotracheal tube."

"…it is reasonable to consider using quantitative waveform capnography in intubated patients to monitor CPR quality, optimize chest compressions, and detect ROSC during chest compressions or when rhythm check reveals an organized rhythm. **If $PetCO_2$ is <10 mm Hg, it is reasonable to consider trying to improve CPR quality by optimizing chest compression parameters.** If $PetCO_2$ abruptly increases to a normal value (35 to 40 mm Hg), it is reasonable to consider that this is an indicator of ROSC."

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THE WALL STREET JOURNAL.

**"If we didn't have the $CO_2$ readings we were getting, we would have terminated efforts much sooner."[1] - Bruce Goodman, Mayo Flight Paramedic**

**Name:** Howard Snitzer

**Age:** 54

**Diagnosis:** Cardiac Arrest

**96 Minutes -** On the 12th defibrillation shock after start, a rise in capnography indicates ROSC.

1. Winslow, R. **"96 minutes without a heartbeat".** *Wall Street Journal.* **May 11, 2011..**

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## THE JOINT COMMISSION *SENTINEL EVENT ALERT*
**ISSUE 49 AUGUST 2012**

*Regarding the safe use of opioids in hospitals*

"In addition to monitoring respiration and sedation, pulse oximetry can be used to monitor oxygenation, and capnography can be used to monitor ventilation. **Staff should be educated not to rely on pulse oximetry alone because pulse oximetry can suggest adequate oxygen saturation in patients who are actively experiencing respiratory depression, especially when supplemental oxygen is being used** – thus the value of using capnography to monitor ventilation. When pulse oximetry or capnography is used, it should be used continuously rather than intermittently."

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## USING CAPNOGRAPHY WITH PATIENT CONTROLLED ANALGESIA

Respiratory depression is more likely to occur when stimulus to the patient (i.e., clinicians, family, etc.) stops

Accurately monitors effective ventilation and respiratory rate, even when clinicians are away from the room

Earliest indicator of:
- Apnea
- Obstruction
- Hypoventilation

Watch for: No breath (apnea), shallow breathing, ↓ RR & ↑ $etCO_2$ trend

Titrate dosage (duration between doses or actual dose amount) according to trends


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## UNIQUE APPLICATIONS OF $ETCO_2$ IN CRITICAL CARE

- Gastric tube placement
- Reduce ABG's and trend a-A gap for improvement
- Passive leg raise test (sepsis)
- DKA

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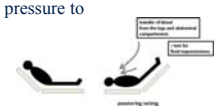
## $ETCO_2$ PREDICTS FLUID RESPONSIVENESS IN PASSIVE LEG RAISING

- 65 ventilated patients needing volume expansion
- Compared changes in $EtCO_2$ with arterial pressure to reflect changes in CO
- **$EtCO_2$ increase ≥ 5% predicted fluid responsiveness (p=0.0001)**
  - Increase in the CI ≥ 15%
  - **Sensitivity 71% (95% CI 48 – 89%) and specificity of 100% (CI 82 – 100%)**
- The changes in $EtCO_2$ induced by a PLR test predicted fluid responsiveness with reliability, while the ***changes in arterial pulse pressure did not.***



Monnet et al (2013) Intensive Care Medicine

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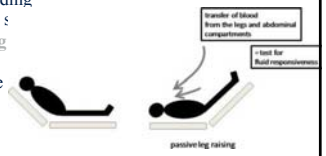
## PASSIVE LEG RAISING

- Patient – HOB 45 degrees
- Obtain Capnography reading
- Initial $EtCO_2$: 34 mmHg
- Lift legs for 1 – 2 minute
- 40 mmHg after 90 sec
- What does the patient need?
- **Fluids!!!!!**

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## CONCLUSION

Respiratory Compromise is COMMON, COSTLY, DEADLY & **PREVENTABLE**

Capnography provides an earlier detection of Respiratory Compromise

You have the power to save lives!

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**QUESTIONS AND COMMENTS**

**THANK YOU!!!**



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