Increasing patient safety with etCO$_2$ monitoring

Jacob Castiel
Capnography and Ventilation training manager
Why monitor etCO₂?

- CO₂ is a compound molecule
  - 2 elements of oxygen and 1 element of carbon
  - colorless and heavier than air
  - a natural waste product of cellular Energy production
  - green plants clean up after our exhaled CO₂

- Capnography comes from the Greek word Kapinos (καπνίζω) - “smoke”
  - smoke from the “fire” of metabolism
So What is Capnography?

- Noninvasive, continuous measurement of exhaled carbon dioxide (EtCO2) concentration over time
  - A numerical value of the EtCO2
  - A distinctive graphic representation of the EtCO2 concentration
  - Respiratory rate detected from the actual airflow
Physiology of Energy Production

Ventilation:
--breath
-ETCO₂
-lungs

Oxygenation:
- alveoli
- muscles & organs
- cells

CO₂

Energy

Oxygen + Glucose

NHS
Factors affecting etCO$_2$ values

- CO$_2$ produced by Metabolizing tissues
- CO$_2$ Carried by blood to the lungs

Production  Delivery  Elimination
Normal Capnography values

35 - 45 mmHg / 4.7 - 6 kPa

- A-B: Baseline - no CO₂ in breath, end of inhalation
- B-C: Rapid rise in CO₂ - Expiration
- C-D: Alveolar Plateau
- D: End expiration (ETCO₂)
- D-E: Inhalation
CO₂ Measurement Methods

- Measurement of CO₂
  - Blood Gas Analysis
  - Breath Gas Analysis
  - Transcutaneous Methods
  - Chemical Detectors
  - Infrared Light Absorption
    - Sidestream
    - Mainstream
Mainstream Capnography

Electronic Cable

EtCO2 IR Sensor
Arterial Blood Gas analysis (ABG)

- ABG is one of the most common tests performed on patients in intensive care units (ICUs).
- An arterial blood gas (ABG) is a blood test that is performed using blood from an artery. It involves puncturing an artery with a thin needle and syringe and drawing a small volume of blood.
- The test is used to determine the pH of the blood, the partial pressure of carbon dioxide and oxygen, and the bicarbonate level.
Sidestream Technology
CO₂ Measurement Methods

Measurement of CO₂

Blood Gas Analysis

Breath Gas Analysis

Transcutaneous Methods

Chemical Detectors

Infrared Light Absorption

Mainstream

Sidestream

Oridion Microstream® Technology
# Microstream® Capnography - Technology Overview

<table>
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<tr>
<th>Detection Technology: Easiest to Use</th>
<th>Patient Interfaces: Crispest, cleanest sampling</th>
<th>Smart Algorithms: Reduce risk and cost</th>
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<tbody>
<tr>
<td>Plug and Play:</td>
<td>Specialty sampling lines for every clinical need</td>
<td>Smart Breath Detection: Eliminates artifact enabling OR quality monitoring on non intubated general floor patients</td>
</tr>
<tr>
<td>No user intervention needed</td>
<td>Tailored for specific populations and procedures in EMS, Critical Care, Cath Lab, Endoscopy, Gen. Floor</td>
<td>Smart Alarm for Respiratory Analysis (SARA™)</td>
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<td>Automatically corrects for pressure,</td>
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<td>Recognizes and suppresses most nuisance alarms without missing real events.</td>
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<td>temperature changes; automatic zero</td>
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<td>Integrated Pulmonary Index™ (IPI™)</td>
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<tr>
<td>Always Accurate</td>
<td></td>
<td>The first and only index that simplifies measurement of the adequacy of ventilation making it accessible to the least trained clinician.</td>
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<tr>
<td>Only CO₂ specific IR Technology</td>
<td>Smart Capnoline Plus:</td>
<td>Apnea Index / Oxygen Desaturation Index</td>
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<tr>
<td>Does not compete with neonatal tidal volume</td>
<td>- Accurate CO₂ and respiration rate sampling from patients who are nasal or oral breathers</td>
<td>Screen sleep disorders in patients in bed so they can be treated safely and referred for revenue generating sleep studies.</td>
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<tr>
<td>Low sample flow rate (50 ml/min)</td>
<td>- Accurate in NIV</td>
<td>HFOV Monitoring Mode</td>
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<td>Neonatal airway adapter 0.5 cc dead space</td>
<td>- Unique O₂ delivery</td>
<td>Break-through technology that allows monitoring of ventilation of patients on HFOV</td>
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<td>15 Microliter sample cell provides a fast response time</td>
<td>- Oral prong for effective breath capture even in shallow breathing</td>
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- **Smart Capnoline Plus:**
  - Accurate CO₂ and respiration rate sampling from patients who are nasal or oral breathers
  - Accurate in NIV
  - Unique O₂ delivery
  - Oral prong for effective breath capture even in shallow breathing
# Market-leading OEM partners

<table>
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<th>Emergency Medicine</th>
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<td>ZOLL</td>
<td>DIXTAL Collaborative Evolution</td>
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<td>Philips</td>
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<td>Athena GTX</td>
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<td>Welch Allyn</td>
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<td>IMPACT Instrumentation, Inc.</td>
<td>Fukuda Denshi</td>
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<td>INSTRAMED</td>
<td>Electrical &amp; Electronics Division (EBG)</td>
<td>IMPACT Instrumentation, Inc.</td>
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Capnography indications and patient safety

**Intubated Patient**

- Recognized misplaced or dislodged endotracheal tube
- Assess sufficient ventilatory support
- Assess effectiveness of resuscitation efforts

**Non-Intubated Patient**

- Monitors adequacy of respiration
- Detects Hypo/Hyperventilation from:
  - Drug overdose: prescription or abuse
  - Drug induced sedation & analgesia
- Ineffective ventilation support / failure to prevent respiratory failure
  - COPD, asthma, CHF, etc.
  - NPPV (CPAP, BiPAP)
The Arterial to End Tidal CO$_2$ Gradient

- EtCO$_2$ = concentration of CO$_2$ exhaled in each breath -35-45 mmHg
- PaCO$_2$ = concentration of CO$_2$ present in arteries -35-45 mmHg
- Normal delta around 2-5 mmHg Difference

PaCO$_2$ > EtCO$_2$
Ventilation-perfusion matching
Ventilation-perfusion mismatching

Perfusion Problems:
- Pulmonary embolism
- Cardiac arrest
- Hypovolemia
Ventilatory Problems:

- Bronchial intubation
- Increased bronchial secretions
- Mucus plugging
- Bronchospasm
- Atelectasis

All values in the examples below are for illustrative purposes only.
17 Statements from 20 Societies in 2 ½ years (~ 7 per year)
NAP4 BJA March 2011 - Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society:

“Capnography, or rather the failure to use it, likely contributed to 17 outcomes of death or brain damage on ICU, including four esophageal intubations and 14 inadvertent tube displacements: these account for 82% of events leading to death or brain damage in ICU.”

“The single most important change that would save lives is the use of a [capnograph], which would have identified or prevented most of the events that were reported. We recommend that a capnograph is used for all patients receiving help with breathing on ICU; current evidence suggests it is used for only a quarter of such patients.”

“Greater use of this device will save lives.”
The AAGBI recommends that:

- Continuous capnography should be used in all anaesthetised patients, regardless of the airway device used or the location of the patient.
- Continuous capnography should be used for all patients whose trachea is intubated, regardless of the location of the patient.
- Continuous capnography should be used for all patients undergoing moderate or deep sedation, and should be available wherever any patients undergoing anaesthesia or moderate or deep sedation are recovered.
- Continuous capnography should be used for all patients undergoing advanced life support.
EBA Recommends:

- All intubated patients should be monitored with continuous capnography, be they in the operating theatres, intensive care units, emergency departments or outside hospital e.g. undergoing CPR
- All patients undergoing moderate or deep sedation should be monitored with continuous capnography.
“Continuous electronic monitoring of oxygenation and ventilation should be available and considered for all patients and would reduce the likelihood of unrecognized clinically significant opioid-induced depression of ventilation in the postoperative period."

“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.”

“APSF is aware of hospital system experiences that support the effectiveness of alternative continuous respiratory monitoring technologies, such as Capnography, in lieu of pulse oximetry.”
February 2012 Intensive Care Society (UK) Guidelines – Procedural Sedation

**Standards for Capnography in Critical Care**

- Capnography during the procedures of tracheostomy or endotracheal intubation in the ICU.
- “Capnography should be used for all intubated and ventilated patients in the ICU.”
- Capnography for patients who require mechanical ventilation during hospital or intra-hospital transfer.
March 2013 Association of Anaesthetists of Great Britain and Ireland

Guidelines: Immediate Post-Anaesthesia Recovery 2013

In the PACU, if patients’ tracheas remain intubated or they have their airways maintained with a supraglottic or other similar airway device, they should be monitored with continuous capnography.

Authored with representatives from:
- Scottish Multiprofessional Anaesthetic Assistants Development Group
- British Anaesthetic and Recovery Nurses Association
- College of Operating Department Practitioners
- Royal College of Anaesthetists
NAP4 follow-up in Scotland  March 2011

- **BJA  Volume 110, Issue 4** Pp. 662-663.
- **Survey of airway management** in scotsland C. Wallace*, B. McGuire and S. Cole

In our initial survey, 54% of units were using continuous waveform capnography on all intubated and ventilator-dependent patients. This figure is very close to the 56% reported by Astin and colleagues across the UK in the same period. At the time, this represented 64% of all such patients.

By 2012, 74% of units reported use on all patients, representing 93% of all ventilator-dependent patients on Scottish ICUs. All but one of the units in Scotland where monitoring equipment was limited or unavailable had plans to introduce capnography at all bed spaces in the future.

while others are working towards this. The layout of these trolleys in many of these trusts is now consistent across the country.
“Continuous Capnography Decreases the Utilization of Blood Gases Society of Critical Care Medicine” (abstract 340).

Rowan, Courtney et al Riley Hospital for Children; Indianapolis USA

Methods:

- Standard continuous capnography was implemented for all mechanically ventilated patients in March 2011. Prior, it was available, but was not routinely used.
- The utilization of blood gas measurement in the paediatric intensive care unit was retrospectively analysed.
- The time period of April 2010 to July 2010 was compared to April 2011 to July 2011.
- Parameters collected included total number of blood gases analysed, cost of blood gas analysis, ventilator days, and patient days.
Continuous Capnography Decreases the Utilization of Blood Gases

Results:

- The total number of blood gases in the time period after the institution of end-tidal CO2 monitoring compared to the year prior decreased from 8667 to 3738.
- The total blood gas charge decreased from $1,487,886 to $717,006 for a total cost savings of $770,880.
- Adjusting for the increased cost of the blood gas analysis and the cost of the ETCO2 monitoring, the total savings over a 4 month period was $835,791. Future months will still be analysed.

Conclusions:

- Continuous scenography resulted in a significant cost savings over a 4 month period by decreasing the utilization of blood gas measurements. Decreasing the number of blood gases analysed may also have other cost savings advantages such as decreased blood transfusions and decreased catheter associated blood stream infections.
Future of Capnography

“Time for Capnography, everywhere.”

- Critical care
- Resuscitation
- Patient transport
- Post operative recovery
- Procedural sedation
- Neonatal resuscitation
- Emergency medicine and respiratory disease

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