Old and New Relationships
CO2 Monitoring and Clinical Applications

- Jim Laging RRT, RCP
- Clinical Specialist Hospital Respiratory Care
- Philips Healthcare
- NRCC 2017

Co2 old and New

- Philips Healthcare has paid for my children’s education and my bills.
- I am an employee of Philips Healthcare North America
- Philips is sponsoring my talk today
Co2 Old and New

• Objectives:
  • 1) describe the relationships between ETCO2 / VCO2 / PaCO2
  • 2) describe the clinical applications of ETCO2 / VCO2 / PaCO2

What Have We Traditionally Used To Monitor Our Patients?
What does Respiratory use?

Pulse oximetry

- Pulse oximeter continuously monitors oxygenation beat by beat
  - Does the oximeter give you $\text{PaO}_2$?
    - No, it monitors oxygen saturation
  - How do we use pulse oximetry?
  - Does the pulse oximeter give you reliable information regarding ventilation status?
Pulse Ox

Goals of Monitoring

• Decrease risk of VILI
  Barotrauma
  Volutrauma
• Decrease ventilator days
• Risk of infection
  VAP
  VAE
Weaning Criteria

Current criteria predicting weaning outcome

- Criteria to assess simple ventilatory parameters (VC, MV)
- Criteria that assess oxygenation (PaO$_2$, PaO$_2$/FiO$_2$)
- Criteria to assess respiratory drive (MIP, P0.1)

“…not accurately reflect the pathophysiology determinants of weaning outcome, since weaning success or failure is multifactorial. Moreover, the indices do not assess the function of other organ systems important for a successful weaning such as the cardiovascular system.”


Need to Access Continuously

Interactions are continuous between cardiac and respiratory parameters

Adequate respiratory & cardiac functions are necessary to maintain supply-demand balance

Need to assess respiratory & cardiac parameters simultaneously
A few basics

Metabolism (CO₂ Production)

CO₂ Elimination (VCO₂)

Things that effect CO₂ Elimination

Circulation
Diffusion
Ventilation
CO₂ Production

Metabolism → Transport → Ventilation

CO₂ Production → PaCO₂ → CO₂ Elimination
Capnography vs. Capnometry

**Capnography**
- Measurement & display capnogram
- Measured by a capnograph

**Capnometry**
- Measurement & display of the ETCO$_2$ value
- Measured by a capnometer

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Capnogram – Valuable Tool

![Capnogram Chart]

- CO$_2$ (mmHg)
- Alveolar Plateau established
- No Alveolar Plateau
## Quantitative vs. Qualitative ETCO₂

#### Quantitative ETCO₂

- Provides actual numeric value
- Found in capnographs and capnometers

#### Qualitative ETCO₂

- Only provides range of values
- Termed CO₂ detectors - Easy Cap

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### Capnography

- Capnography affords the clinician breath by breath trending of ETCO₂ and thus a non-invasive look at ventilation
- Provides an objective reason for ABG’s
- Trend ETCO₂/PaCO₂ gradient to observe patient improvement
  - Changes in ventilation and perfusion are often observed by trending the gradient
Normal Arterial & ETCO₂ Values

Normal PaCO₂ Values
35 - 45 mmHg

Normal ETCO₂ Values:
30 - 43 mmHg

The Gradient is a Good Thing

Why?
• Lets clinicians know when patient status improves
  – PaCO₂/ETCO₂ gradient narrows
• Aids in determining what caused a drop in ETCO₂
  – If ventilation hasn’t changed a sudden and large drop in ETCO₂ usually indicates a change in perfusion.
ETCO₂ = 33 mmHg

PaCO₂ = 53 mmHg

Alveoli that do not take part in gas exchange will still have no CO₂ – Therefore they will dilute the CO₂ from the alveoli that were perfused

The result is a widened ETCO₂ to PaCO₂ Gradient

Why is monitoring Vd/Vt and Vdalv important?

• Vd/Vt is the physiologic (airway deadspace + alveolar deadspace) to tidal volume ratio
  – This value will increase as the patient deteriorates and the V/Q mismatch increases, or you add something between the tube and the circuit
• Alveolar deadspace (Vdalv) is the amount of alveolar tidal volume that didn’t take part in gas exchange
  – In healthy lungs the value is zero
  – Positive pressure ventilation increases Vdalv
  – As the patient start to deteriorate and ventilation to perfusion is mismatched this value will increase
Integration of flow and CO2

- The integration of CO₂ and Flow provides an easy method to obtain previously difficult to obtain parameters
  - VCO₂ = CO₂ Elimination
  - Airway Deadspace, Physiologic Vd/Vt
  - Alveolar Ventilation
  - Cardiac Output

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Airway deadspace vs. alveolar VT

- Airway Deadspace vs. Alveolar VT – why should you care?
  - The vent tells you how much VT enters the lungs and how much comes out
  - What’s more important is how much of the delivered VT was available for gas exchange

- Airway deadspace is the amount of delivered VT that is wasted ventilation
  - Anatomical Deadspace + anything you put between the ETT or trach and the wye of the patient circuit

- Alveolar VT is the amount of delivered tidal volume that reaches the part of the lung where gas exchange takes place
Guide Weaning Process

Vd/Vt is a single variable that defines total cardiorespiratory system efficiency and can predict successful extubation.

“A Vd/Vt ratio less than 0.50 reliably predicts successful extubation whereas a Vd/Vt ratio greater than 0.65 correlates with extubation failure.”

Dead Space to Tidal Volume Ratio (Vd/Vt) Predicts Successful Extubation in Infants and Children – Christopher Hubble MD, Mike Gentle RRT, Donna Tripp RRT, Damian Craig MS, Jon Meliones MD, FCCM, Ira Cheifetz MD – Critical Care Medicine, Vol. 28, No. 6 – June 2000

- Deadspace fraction
- Elevated in early ARDS: 0.58 ± 0.09
- Higher in patients who died (0.63±0.10 vs. 0.54±0.10)
- For every 0.5↑, odds of death ↑by 45%

Figure 1. The Observed Mortality According to the Quintile of Dead-Space Fraction in 179 Patients with the Acute Respiratory Distress Syndrome.
Available tidal volume ?

- For the past few years, mostly because of the ARDS Net study, we have been using lower tidal volumes for mechanically ventilated patients.

- Prior to 2000 a 70 kg patient might have a set VT about 700 ml.

- Today the 4 to 8 ml per kg may result in a set VT of 500 ml. However, airway deadspace reduces the VT available for gas exchange dramatically (500 – 225 = 275 ml).


Evaluate ventilator settings

Knowing how much of the delivered VT is available for gas exchange is important – if the patient is fighting the vent and restless, the issue may be ↓ alveolar VT.
Evaluate Ventilator settings

Role of PEEP

• Benefits:
  • Reduces intrapulmonary shunt
  • Improves arterial oxygenation
• Adverse Effects:
  ⬇️ Cardiac Output
  ⬆️ Dead Space
  ⬆️ Lung volume & stretch during inspiration
VCO2 waveform

Important parameters

X = Total Amount of CO2 Eliminated

Y = Alveolar Deadspace

Z = Airway Deadspace
Profusion vs Ventilation Problem?
Volumetric CO2

EtCO₂ = 32 mmHg  
Vt = 600 ml 
VCO₂ = 50 ml/min

EtCO₂ = 32 mmHg  
Vt = 800 ml 
VCO₂ = 200 ml/min

EtCO₂ = 32 mmHg  
Vt = 1000 ml 
VCO₂ = 300 ml/min

Patient Selection for Weaning

- Patient Condition
  - Afebrile and hemodynamically stable
  - Acceptable chest x-ray
  - Patient is awake and alert
  - Blood gases normalized

- Respiratory Monitoring
  - RR < 30/min
  - SpO₂ > 94%
  - Cdyn >22 ml/cmH₂O
  - NIF >-20 cmH₂O
  - MValv < 8 L/min
  - VCO₂ stable, <3.5 ml/min/kg
  - Vd/Vt <0.60
What happens when a patient fails weaning?

- Without objective criteria
  - Patient tires and fails trial
  - May take several days to recover
- With objective criteria
  - Trial is stopped before patient is exhausted
  - Patent is save complication associated with failure

When Do You Want Your Parachute To Open?
Questions?

Jim Laging
jim.laging@Philips.com
773-573-9155