CAPNOGRAPHY in the SLEEP CENTER

Julie DeWitte, RCP, RPSGT, RST
Assistant Department Administrator
Kaiser Permanente Fontana Sleep Center
Conflict of Interest Disclosures
Speaker:

1. I do not have any potential conflicts of interest to disclose, OR

2. I wish to disclose the following potential conflicts of interest:

<table>
<thead>
<tr>
<th>Type of Potential Conflict</th>
<th>Details of Potential Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grant/Research Support</td>
<td></td>
</tr>
<tr>
<td>Consultant</td>
<td></td>
</tr>
<tr>
<td>Speakers’ Bureaus</td>
<td></td>
</tr>
<tr>
<td>Financial support</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

3. The material presented in this lecture has no relationship with any of these potential conflicts, OR

4. This talk presents material that is related to one or more of these potential conflicts, and the following objective references are provided as support for this lecture:
Learning Objectives

- The future of in-laboratory polysomnography testing
- Demonstrate the importance of capnography during polysomnography
- Transcutaneous vs end-tidal CO$_2$ monitoring
- Review the interpretation of CO$_2$ monitoring data and recognizing improper values.
Trends in Sleep Medicine
CURRENT

OSA (8%)
Hypoventilation Hypoxemia (29%)
CSA (19%)
Pediatric (27%)
Commercial drivers (5%)
PLMD (2%)
Parasomnias (2%)
Other (2%)
Polysomnography Skills

- Technologist
  - Clinical Assessment
  - Capnography
  - Transcutaneous Monitoring

- Diagnostics
  - VAPS
  - ASV
  - Oxygen
  - MATRx/Provent

- Complex Therapy
Different Positive Airway Pressure Modalities

**CPAP \ APAP**
Obstructive Sleep Apnea

**BiLevel Therapy**
OSA -- Aerophagia
Hypoventilation Syndromes
(i.e. Neuromuscular Disease, COPD, Obesity Hypoventilation)

**Adaptive Servoventilation (ASV)**
CSA with/without Cheyne Stokes Respirations
(i.e. Due to Head Trauma or Narcotic Medication Use)

**Volume Assured Pressure Support (VAPS)**
Chronic Hypercapnic Respiratory Failure
COPD, Obesity Hypoventilation Syndrome
Neuromuscular Weakness
Congenital Central Hypoventilation Syndromes
Pathophysiology
Causes of Hypoxemia

- V/Q mismatch
- Shunt
- Diffusion Impairment
- Decreased O2 tension
- Hypoventilation

Pathophysiologic Mechanisms

- Significant obstructive and restrictive ventilatory defects
  - Obesity Hypoventilation Syndrome
  - COPD
- Neuromuscular weakness
  - ALS
  - Muscular dystrophy

Normal PaO2: 80–100mmHg
Normal SpO2: 90 – 100% Adults
Normal SpO2: ≥ 95% Pediatrics

Hypoventilation Syndromes
Hypoventilation
Obesity & Hypercapnia

1141 Patients with OSA

Laaban, JF. Chest 2005; 127:710
Calculation of CO₂ Balance

Stable Ventilation

Cycle 1

Hypopnea

Interevent

Cycle 2

Apnea

Interevent

Airflow

Metabolic CO₂ production

CO₂ excretion

CO₂ (ml)

Time

Slide courtesy of David Rapaport, MD
Combined Effect of Interevent Ventilation + Duration
(1 patient - all cycles)

Event/Interevent Duration Ratio

Interevent $V_E$ (% awake steady-state $V_E$)

- Cycle CO$_2$ balance - negative
- Cycle CO$_2$ balance - positive

Maintain PaCO$_2$ constant

Derived from computer model

Slide courtesy of David Rapaport, MD
Development of Chronic Hypercapnia

- Reduced HCO₃ Excretion Rate
- Normal Development of Chronic Hypercapnia

Awake PaCO₂ (mmHg)

Day

Awake Blood HCO₃ (mEq/l)

Day

↓ HCO₃ excretion rate

↓ CO₂ Response (0.5 l/min/torr)

↓ CO₂ Response & ↓ HCO₃ excretion rate

Microsoft PowerPoint Chart

Norman, Goldring, Clain, Oppenheimer, Charney, Rapoport, Berger. JAP 2006; 100:1733.
Hypoventilation/Hypoxemia Evaluation

**What do we look for?**

**Clinical Assessment:**
- PFT Results
- Lab Results
- Echocardiogram
- Baseline
  - Oxygenation:
  - SpO2/CO2 (awake upright/supine)
- Exam

**Diagnostic**
- Watch for Obstructive and/or Central Apnea
- Monitor SpO2 baseline
- **Closely monitor for Hypercapnia**
- Monitor NREM vs REM
- Body Position
- What’s the apnea-interapnea ratio?

**Therapy**
- CPAP
- BIPAP
  - Volume Assured Pressure Support (VAPS)
- Oxygen
Voluntary Hyperventilation

Normal Breathing

Voluntary Hyperventilation

Leech J. Chest, 1991; 100:1334

Slide courtesy of David Rapaport, MD
Example: High apnea to interapnea ratio

85% 73mmHg 56%
CPAP Therapy

91%

45mmHg
Treatment

Requires specific treatment for different pathophysiology:

- **Airway obstruction**: EPAP
- **Hypoventilation**: IPAP (IPAP-EPAP)
- **Persistent Hypoxemia?**: Oxygen
- **VAPS**: IPAP EPAP
VAPS Settings

Hypoventilation Protocol

**Start Settings**

- IPAP Max to 30cmH20
- IPAP Min 4cmH20 above EPAP
- EPAP start at last CPAP setting that cleared obstruction

CPAP to clear obstructive apnea

Increase EPAP by 1 cmH20 for obstructive apnea, hypopnea, or excessive snoring

**Goals:**

- C02 & O2 improvement

Tidal Volume 6-8 ml/kg

Set Respiratory Rate: 0-30
Neuromuscular Evaluation Protocol

Diagnosis:
- Amyotrophic Lateral Sclerosis (ALS)
- Muscular Dystrophy
- Spinal Muscular Atrophy (SMA)

Clinical Assessment
Follow Hypoventilation Evaluation & in addition:
**Respiratory Rate**
Imperative to monitor closely
Compare wake rate to sleeping rate

Diagnostic
- O2 saturation and CO2
- Respiratory Rate

Therapy
- VAPS even without hypercapnia
- Target CO2 35mmHg
Non-invasive methods of measuring CO2

Capnography
The “OTHER” Vital Sign
ETCO2 WAVEFORM

- Tachypnea
- Obstructive ventilatory defect
- Obstruction (kink) in ETCO2 system
TRANSCUTANEOUS MONITOR

Continuous C02 monitoring

Early detection of hypoxia

Immediate ventilation status

Optimize management of complex patients

Transcutaneous Monitor:
TcpC02 Normal: 35-45mmHg
Normal PaCO2: 35-45mmHg
# TCO2 versus ETCO2

<table>
<thead>
<tr>
<th></th>
<th>Transcutaneous</th>
<th>ETCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>• Mimics arterial blood</td>
<td>• Breath-to-breath CO2 analysis</td>
</tr>
<tr>
<td></td>
<td>• Trends CO2</td>
<td>• Simple to use</td>
</tr>
<tr>
<td></td>
<td>• Ability to assess CO2 with PAP therapy</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>• Low Perfusion</td>
<td>• Underestimates PaCO2 with tachypnea and disease processes with increased dead-space</td>
</tr>
<tr>
<td></td>
<td>• Heat sensitivity</td>
<td>• Limited ability to assess CO2 with PAP therapy</td>
</tr>
</tbody>
</table>
Case Presentations
Case #1

- 44 yr old female
- 5’ 1” height, 457 lbs weight (BMI 86)
- History of heart failure & obstructive sleep apnea
- Recently discharged from the hospital for acute respiratory failure
Awake

**Sitting**

**Supine**
Sleep

NREM

REM
Therapy

CPAP

Bilevel PAP (VAPS)
Follow-up

- Diagnosis: Obesity Hypoventilation Syndrome
- VAPS initiated
- Oximetry w/ AVAPS showed SaO$_2$ mostly 85-90%
- 2 LPM O$_2$ added via tube adapter
- Over 6 months:
  - Clinic Transcutaneous CO$_2$ 55 to 48mmHg
  - Serum bicarbonate 38 to 30
Case #2

• 50 year old man with ALS

• Chief complaint— wakes up gasping for air and has difficulty laying flat

• FVC 37%
50 year old ALS
Follow-up

- VAPS started with difficulty tolerating
- Decreased Bilevel PAP to 10/4 cmH20 and remotely increased IPAP gradually up to 18 with improvement in symptoms.
- Patient declined tracheostomy
- Used VAPS around the clock (awake and sleep)
Case #3

• 10 year old boy with Duchenne’s Muscular Dystrophy.
• Developed frequent falling episodes.
• He is now non-ambulatory.
• Awakes feeling short of breath.
• Pulmonary Function Testing: FVC 55%
Wake Transitioning into Sleep

Example: Artificially low TCM CO2
Troubleshooting Transcutaneous CO2 monitoring

• Check electrode site
• Inspect fixation ring
• Check connections
• Calibrate electrode
• Calibrate TCM to sleep system
• Change electrode sensor
• Change TCM monitor
ETCO$_2$ LOSS OF WAVEFORM

POSSIBLE CAUSES:

- Obstructive Apnea Event
- Dislodged Circuit (cannula out of nose, kinked tubing)
- Occluded Water Trap
- Open Mouth Breathing
NREM

30 seconds

What’s the next step?

Bilevel PAP
Case #4

- 5 week old girl, ex 29 week premature infant
- Admitted to NICU (neonatal intensive care unit) with Apparent Life Threatening Event (ALTE)
- After feeding, infant appeared to stop breathing and turned blue.
What’s the diagnosis?  How would you treat this patient?
Follow-up

- Diagnosis: Apnea of Prematurity
- Therapy: 0.125 LPM oxygen (initially around the clock)
- PSG nap study performed monthly with gradual improvement
- Resolved at 7 months
Conclusion / Learning Points

1. Increasing complexity of overnight sleep testing

2. Capnography is critical for diagnostic evaluation and assessing therapy response

3. Dual capnography is helpful to confirm values and provide backup assessment

4. Transcutaneous CO2 (TCM) monitoring may provide more reliable CO2 values for diagnostic evaluation

5. TCM CO2 provides better ability to assess response to therapy (PAP or O2)

6. TCM devices w/dual oximetry beneficial especially for infants!
Acknowledgements

Dennis Hwang, MD
Medical Director, Kaiser Permanente Fontana Sleep Center
Regional Co-Chair, Sleep Medicine (Southern California Permanente Group)
AASM, Chair EHR Integration Task Force
AASM, Telemedicine Task Force
AASM, AMA RVU Update Committee Advisor