The Advantages of Transcutaneous $\text{CO}_2$
Over End-Tidal $\text{CO}_2$ for Sleep Studies

PET$\text{CO}_2$ vs. TCPC$\text{CO}_2$

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The Advantages of Transcutaneous CO₂ Over End-Tidal CO₂ for Sleep Monitoring
Disclosure

I have received an honorarium for this lecture but have not entered into any business agreements with Radiometer America Inc.
Objectives

* Summarize the CO₂ measurement landscape and distinguish between the various methods currently in use
* Identify the advances in the technology of transcutaneous CO₂ monitoring
* Compare the detection accuracy and trend prediction capabilities of transcutaneous CO₂ vs. the end-tidal method
* Appraise the benefits of early detection of CO₂ trending to a cross-section of patients
Incidence of sleep disordered breathing is increasing due to increased awareness of sleep disordered breathing

More media coverage with regard to poor sleep leading to automobile and other accidents

Availability of testing methods including home sleep studies
Sleep Studies - Landscape

- Encouragement for home studies
- Lab based polysomnogram remains to be Gold Standard
- Detection of nocturnal seizures – extended EEG montage
- Diagnosis of parasomnias
  - RBD (REM Behavior Disorder)
  - Catathrenia
Importance of Sleep Diagnostics

- Estimated that 18 million Americans suffer from a sleep disorder or sleep apnea
- 10 million of them have not been diagnosed
- In the last 10 years Sleep Medicine has seen tremendous growth worldwide
- Patients of all ages from newborns to geriatric can be affected by sleep disorders
- There is increased awareness among general practitioners and detection of the diseases has increased
Consequences of Sleep Disorder Breathing

- Increased weight gain leading to obesity epidemic
- Decreased vigilance during the day
- Sleep disturbances
- GERD
- Difficulty getting up in the morning
- Insulin resistance leading to Type 2 diabetes
- Memory loss
Consequences of Sleep Disorder
Breathing in Children

* Sleep disturbances
* Difficulty waking up in the morning to go to school
* Teenagers engaging in risk taking behaviors
  * Drug use
  * Smoking
* Depression
* Toddlers may exhibit hyperactive behavioral issues
Increasing the life expectancy to almost 80 years in 2012

- Having patients with Alzheimer’s disease, dementia, dementia with lewy bodies
Increased Incidence in Children

- More and more premature babies are surviving
- Survivability of children with other neuromuscular dysfunctions
  - Cerebral Palsy
  - Seizure disorder
  - Chest surgeries
Measurement of Carbon Dioxide During Sleep Studies

- Not always done
- Provides essential information about patients ventilatory status
- Complementary to measurement of oxygen saturation
- Especially valuable in patients with chronic lung disease and REM Sleep
- **Hence, crucial in sleep studies**
Patients at Risk for Hypoventilation

- Neuromuscular weakness
- Congenital Central Hypoventilation Syndrome (CCHS)
- Obesity-related hypoventilation
- Muscle weakness
Assessment of Hypoventilation

During Polysomnography

- $\text{CO}_2 \geq 50$ Torr
- Low baseline saturation ($\leq 90\%$)
- Decreased flow and effort
- EEG Arousals

- PAP Titrations
- Oxygen Titrations
- Mechanical
- Ventilation
Measurement of Carbon Dioxide During Sleep Studies

* Monitor of Co$_2$ during sleep should be a part of sleep studies
* Can you imagine doing a PSG without SAO$_2$? (The study would be incomplete)
CO$_2$ Monitoring Consists of Three Methods

- Blood Gas (ABG)
- End-Tidal CO$_2$ (ETCO$_2$)
- Transcutaneous CO$_2$ (PtcCO$_2$)
Monitoring Carbon Dioxide

- Blood gases
- Gold Standard
- Random sampling does not require indwelling arterial line
- Well Validated
- Not practical in sleep lab
- Not accurate due to pain, anticipating of pain, hyperventilation
- Sampling error (too much heparin, air)
Blood Gas (ABG)

**Advantages**
- Arterial blood gas (ABG) measurements are the gold standard
- An ABG is fast and accurate
- On the spot checks for PaCO₂

**Challenges**
- Not ideal for sleep studies
- The procedure is invasive
- Random sampling cannot correlate with stage of sleep
Arterial Line

- Not practical in sleep lab
- Invasive
- Complications
- Needs heparin
- Provides access to random sampling without waking patient
Both techniques are non invasive
* Well Validated
* Quantitative indirect predictions of arterial carbon dioxide level
* Both have been widely adopted in sleep studies
* Trends in $\text{CO}_2$ changes can be monitored

Valerie Kirk et al, University of Calgary, Canada, Sleep, 2005
Results

- 609 Children
- 363 Male
- Age: 7.9 ± 4.6 yeas
- Maximum and mean Co$_2$ measurements obtained

<table>
<thead>
<tr>
<th></th>
<th>Interpretable data (total recording time)</th>
<th>Maximum CO$_2$</th>
<th>Mean CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETCO$_2$</td>
<td>61.8% +/- 35.1%</td>
<td>0.1 +/- 5.4 mm Hg</td>
<td>0.6 +/- 3.9 mm Hg</td>
</tr>
<tr>
<td>PtcCO$_2$</td>
<td>71.5% +/- 25.2%</td>
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<td></td>
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</table>

Valerie Kirk et al, University of Calgary, Canada, Sleep, 2005
TCP CO₂ and end-tidal Co₂ monitoring during PSG are well tolerated and provide interpretable and comparable results in the majority of children.

Valerie Kirk et al, University of Calgary, Canada, Sleep, 2005
Transcutaneous and end-tidal Co$_2$ pressures should be measured during pediatric PSG


* 15 patients referred to Montreal Children’s Hospital Sleep Lab

* 5,159 – 30 sec epochs were analyzed
### Prospective Study of 15 Pediatric Sleep Studies

<table>
<thead>
<tr>
<th></th>
<th>Signal Integrity (of 30 second epochs)</th>
<th>Exceeded Mean CO$_2$ in ETCO$_2$</th>
<th>10 of 15 studies</th>
<th>Increased CO$_2$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETCO$_2$</td>
<td>73%</td>
<td>-</td>
<td>$\leq 4$ mm Hg</td>
<td>70% increase in readable CO$_2$ values</td>
</tr>
<tr>
<td>PtcCO$_2$</td>
<td>78.5%</td>
<td>2.8 +/- 3.0 mm Hg</td>
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</tbody>
</table>
* PtcCo₂, as well as PETCo₂ should be measured
* For an individual subject there was a constant and usually close relationship to PtcCo₂ and PETCo₂. PtcCo₂ monitoring was particularly useful for children who would not tolerate a nasal sampling tube
* Children with moderate to severe airway obstruction PtcCo₂ was useful and better tolerated

In children with tachypnea or increased dead space PETCo₂ underestimates Co₂ levels

Infant who would not tolerate a nasal sampling catheter had no PETCo₂ data
“... it has been our experience that in some children it can be extraordinarily difficult to keep a nasal sampling catheter in place during sleep to sample PETCo₂ ...”
Challenge of End-Tidal CO$_2$ Monitoring

- Not accurate in the following scenarios:
  - Patient is a mouth breather
  - Patient has underlying lung disease that leads to significant air trapping
  - Dead space with non communicating airways
  - Higher respiratory rates
  - Excessive moisture
End-Tidal CO$_2$ (ETCO$_2$) Sampling

- Side-stream
  - ETCO$_2$ collection
  - Unit calibration
  - Sleep system calibration
  - Dehumidification tubing
  - Filters
Side-Stream ETCO$_2$

- Infrared sensor
- Zero and reference calibration
- Nasal cannula
- Dehumidification tubing
Transcutaneous Monitor
TCOM Probe
Advances in TCOM Unit Technology

- Gold plated membrane
- Reminder to change the membrane
- Clip-on ear lobe probe
- Intuitive color touch screen and Windows CE software for increased user-friendliness
- High compatibility to interface with any patient monitoring system
- On-board video tutorials
- Built-in battery facilitates transport of the patient
- Simultaneous viewing of all measurements
- USB port for easy printing of reports
American Academy of Sleep Medicine’s
Best Clinical Practice

“Transcutaneous or end-tidal PCO₂ may be used to adjust NIPPV settings if adequately calibrated and ideally validated with arterial blood gas testing”
Transcutaneous monitoring in the sleep lab is well established and reliable. The CO$_2$ data from transcutaneous monitoring should be used to evaluate ventilation, hypoventilation, titrate PAP and titrate oxygen during polysomnograms.
Safe sleep with tcpCO₂ monitoring

"Monitoring of CO₂ during sleep should be part of sleep studies"

JC Winck MD, Professor, Auxiliar Candidate Pulmonology, Paris, and AK Simone MD, Consultant in respiratory medicine, London [1]
Advantages of ETCO$_2$ Monitoring

- Instant breath by breath analysis
- Non-invasive
- Easily connects to sleep lab computers
- The unit is portable and has battery backup power
Challenges of ETCO$_2$ Monitoring

- Single nare breathing
- Proper sized cannulas
- Mouth breathing
- Lag time
- Higher respiratory rates
- High flows from CPAP, ventilator or oxygen
- Excess moisture
Advantages of Transcutaneous (PtcCO$_2$)

- Trends CO$_2$
- Noninvasive
- Reliable
- Portable
Challenges of Transcutaneous Monitoring

- Probe site
- Erythema
- Staff competency
- Start time

3Martin. RJ. Transcutaneous monitoring: instrumentation and clinical applications. Respir Care 1990;35(6):577-583
Limitations of Transcutaneous CO$_2$ Monitoring

- Insufficient electrode temperature may adversely influence performance
- Performance may be suboptimal over poorly perfused area
- Use of heated electrode may cause the skin to blister, especially in a child with delicate skin
- Compromised hemodynamic status may cause inaccurate PtcO$_2$ monitor values
Future

- Moderate Sedation
- Patients on vents
  * Physician’s office
- Neonatal ICU
  * ? Interventricular hemorrhage
  * Pediatric intensive care
  * High frequency positive pressure ventilation
- Chronic lung disease of prematurity (BPD)
- COPD
Conclusions

* Sleep disordered breathing is not uncommon
* Patients of all ages from newborn to geriatric can be affected by sleep disorders
* SDB still remains under recognized and under appreciated
* Increased incidence and awareness among general practitioners
* Monitoring $\text{CO}_2$ should be a part of sleep study
* Not all sleep studies include monitoring $\text{CO}_2$
Conclusions continued

- Sleep study should include continuous monitoring Co$_2$.
- Valuable especially in REM sleep and in patients with underlying medical conditions like CLD (chronic lung disease of prematurity), COPD, asthma, diaphragmatic paralysis.