Achieving Restful Ventilation: The Impact of Patient-Ventilator Interaction on Sleep

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Disclosure Statement

I have received a research grant from Covidien for a clinical research assistant.
Case Scenario: Sleepless in ICU

- 56 year old male
- 40 pack year smoker, obese, hypertension
- Critical illness now resolved
- Prolonged wean from mechanical ventilation
- Tracheostomy
- Looks comfortable on PSV 12 cmH₂O, PEEP 5
- Develops distress within 1-2 hr of trach-mask trials
- Nurses say he “hardly gets any sleep”
Audience Poll

1. How do you ventilate this patient at night to ensure he is well-rested the next day?

   - Increase Pressure Support level?
   - Assist – Control mode?
   - Continue attempts to wean PSV overnight?

*Do ventilator settings impact sleep quality?*
Outline

• Is sleep quality in ICU important?
• What happens to breathing pattern during sleep
  – Normal, healthy person
  – Ventilated patient
• Patient-ventilator interaction and sleep
  – Central Apnea
  – Asynchrony (eg. Ineffective efforts)
• How should we set the ventilator to promote better sleep quality?
Sleep Quality in the ICU

- **Highly fragmented**
  - 20-80 arousals and awakenings per hour sleep
- **Abnormal sleep architecture**
  - severely reduced slow wave sleep
  - Reduced to absent REM sleep
- **Disruption of circadian rhythm**
  - 50% of sleep occurs during the day
Impact of Poor Sleep Quality in ICU

• 61% of ICU patients reported sleep deprivation

• Being unable to sleep ranked among the highest stressors by patients
  – Biancofiore, G. Liver Transplantation, 2005;11(8): 967-972

• Associated with Late NIV failure
  – Campo, F. Crit Care Med, 2010; 38 (Epub ahead of print)

• May contribute to delirium
  – Campo, F. Crit Care Med, 2010; 38 (Epub ahead of print)
Polysomnography is the gold standard for sleep measurement.
ICU Sleep Research
Outline

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Normal Breathing Pattern During Sleep

- Downregulation of respiratory muscles
- Decreased VE due to decreased Vt
- CO$_2$ rises: 2-4 mmHg higher during sleep
- REM sleep: paralysis of major muscle groups with exception of diaphragm and upper airway muscles
- RR highly variable
From Wakefulness to Sleep on PSV and ACV

Parthasarathy S. & Tobin MJ.
Am J Respir Crit Care Med 2002; 166:1423-1429
Central Apnea ↔ Over-ventilation

• Patient’s respiratory drive decreases in response to decreased minute ventilation requirements, but minute ventilation provided by ventilator does not decrease proportionally
  – CO₂ falls below the apneic threshold
  – Patient stops making respiratory efforts
  – CO₂ rises above apneic threshold
  – Respiratory efforts resume

• “physiologic apnea” – pH may be normal to alkalotic
  – *not to be confused with drug-induced apnea – if untreated, pH < 7.35
Central Apnea

• More common during sleep
• More common in patients with CHF
• More common with higher levels of ventilatory support (without set back-up rate)
Do central apneas disrupt sleep?
Effect of Ventilator Mode on Sleep Quality in Critically Ill Patients

Sairam Parthasarathy and Martin J. Tobin

Am J Respir Crit Care Med Vol 166. pp 1423-1429, 2002

• 11 ICU patients
• Polysomnography
• Spent 2 hours each on ACV (Vt 8 ml/kg), PSV (targeting 8 ml/kg)
• Arousals and awakenings from sleep
Central Apneas

![Graph showing apneas per hour with pressure support and pressure support with dead space, with statistical significance indicated by p < 0.05 and p < 0.01.]
### Central Apneas Increase Sleep Fragmentation

<table>
<thead>
<tr>
<th></th>
<th>AC</th>
<th>PSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arousal + Awakenings (# / hr sleep)</td>
<td>54 ± 7*</td>
<td>79 ± 7</td>
</tr>
<tr>
<td>Central Apneas (# of patients)</td>
<td>0 /11*</td>
<td>6 /11</td>
</tr>
<tr>
<td>Apnea-related arousals + awakenings (# / hr)</td>
<td>0*</td>
<td>23 ± 7</td>
</tr>
</tbody>
</table>

*significantly different from PSV p < 0.05

Parthasarathy and Tobin
Am J Respir Crit Care Med 2002; 166:1423-1429
Parthasarathy and Tobin study

- Arousal + awakenings / hr sleep
- All Patients
- Patients with apneas
- Patients without apneas

Graph showing data for different conditions and groups.
### Patient-Ventilator Asynchrony

<table>
<thead>
<tr>
<th></th>
<th>Patient Breath</th>
<th>Ventilator Breath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ineffective Efforts</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Autotriggering</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Double Triggering</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Delayed Cycling</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Asynchrony: Ineffective Triggering

• Patient effort < PEEPi + set trigger sensitivity

• More common during sleep
  – Fanfulla, F. Resp Med 2007;101: 1702

• More common with higher PSV levels
  – Giannouli, E. AJRCCM 1999
Does patient-ventilator asynchrony disrupt sleep?
• 13 stable ICU patients weaning from MV
• 2 modes: PSV and PAV (Evita 4, Dräger)
• Level of support set to offload work of breathing by 50% relative to spontaneous breathing
• 2 consecutive nights on PAV and PSV (random order) recording sleep and breathing pattern
Asynchrony Causes Sleep Disruption

<table>
<thead>
<tr>
<th></th>
<th>PAV</th>
<th>PSV</th>
<th>Pvalue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apneas (n patients)</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Total Asynchronies (n/h)</td>
<td>23.7 ± 15.4</td>
<td>52.9 ± 59.2*</td>
<td>0.02</td>
</tr>
<tr>
<td>Arousals/h</td>
<td>12.8 ± 10.3</td>
<td>25.6 ± 23.2</td>
<td>0.02</td>
</tr>
<tr>
<td>Arousals + awakenings/h</td>
<td>18.0 ± 10.4</td>
<td>33.9 ± 28.9</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Bosma, K. Crit Care Med. 2007; 35(4):1048-54
Incidence of Asynchrony prior to arousal vs. period of undisrupted sleep

*p < 0.0001 for both PSV and PAV (pooled data, chi square)
Overall Sleep Quality

Multivariate ANOVA  PAV vs. PSV  *p<0.05

Bosma, K. Crit Care Med. 2007; 35(4):1048-54
Excessive Ventilator Support Increases Asynchrony and Sleep Fragmentation

Bosma, K. Crit Care Med. 2007; 35(4):1048-54
Outline

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• How should we set the ventilator to promote better sleep quality?
20 patients with acute on chronic respiratory failure
Studied night before planned extubation
Controlled mechanical ventilation vs. low PSV
  – ACV started at 10 ml/kg and rate 12 breaths/min
    • Increased settings until spontaneous efforts abolished
  – PSV set at 6 cmH$_2$O
    • Lowest level to compensate for resistance of tube and circuit
AVC then low PSV vs. Low PSV then ACV
Results

• No central apneas were observed in either night

• Considering the whole night, 10 pm to 6 am, irrespective of the order of ventilator settings:
  
  • No difference in arousals+awakenings/hr
    – (ACV 7.5 ± 5.0 vs. 6.5 ± 4.9 PSV, p=NS)

• No significant difference in sleep stages
Toublanc, B. Intensive Care Med. 2007; 33: 1148-54
Caveats to Interpreting these Studies

- What outcome is reported?
- Many facets to sleep:
  - Quantity
  - Quality (time spent in deep sleep or REM sleep)
  - Fragmentation (# arousals + awakenings / hr)
- What matters most to the critically ill patient??
- There is no global index for sleep quality
- And, we don’t know that improving sleep improves outcome…
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• How should we set the ventilator to promote better sleep quality?
What ventilator mode should we use?

<table>
<thead>
<tr>
<th>Hrs /mode</th>
<th>Tobin (n=11)</th>
<th>Brochard (n=15)</th>
<th>Jounieaux (n=20)</th>
<th>Ranieri (n=13)</th>
<th>Georgopoulos (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>6 *</td>
<td>4</td>
<td>&gt;8</td>
<td>2</td>
</tr>
</tbody>
</table>

- **ACV**
- **PSV**
- **PAV**
Clinical Implications

• Any mode/settings that provide inadequate support or excessive support will likely result in poor sleep

• In any mode, adjusting settings to optimize patient-ventilator synchrony will likely improve sleep
Conclusions

- PAV (set properly) makes central apneas rare, ensures good patient-ventilator synchrony, may make life easier for the RT, and appears to improve sleep
  - *Let the patient drive the ventilator*

- Controlled mechanical ventilation eliminates central apneas, obviates the need for synchronization, and also appears to improve sleep
  - *Let the ventilator drive the patient*
Conclusions

• No direct comparison of PAV and ACV… yet

• What is better for weaning:

  Complete rest of respiratory muscles
  (disuse atrophy?)
  vs.
  Maintaining spontaneous breathing
  (muscle fatigue)??
Future Research

• Dr R. Kacmarek, Boston, Mass
  – PAV vs PSV for weaning and sleep quality
  – [www.clinicaltrials.gov](http://www.clinicaltrials.gov)

• Dr. K. Bosma, London, ON
  – PAV vs PSV vs ACV for sleep quality
  – PAV vs PSV for weaning

• Dr. M. Ranieri, Torino, Italy
  – PAV vs ACV vs NAVA for sleep quality
Thank you!

Any Questions?