Clinical Use Of Loop Gain Measures To Determine CPAP Efficacy In Patients With Complex Sleep Apnea

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Disclosures

• Dr. Kristin Robinson – none

• Dr. Michael Stanchina - none
Introduction

• Sleep disordered breathing remains prevalent but underdiagnosed
  – 24% men, 9% women (ages 30-60)
  – Associated with significant morbidity if untreated

• Two main types of sleep disordered breathing
  – Obstructive
  – Central
• **Obstructive Sleep Apnea**
  – Upper airway obstruction
    • Reduced upper airway muscle tone
    • Obesity
  – Rx: CPAP

• **Central Sleep Apnea**
  – Upper airway remains patent
  – Central respiratory control problem
  – Narcotics, CHF
  – Rx:
    • treat underlying cause
    • CPAP

**Polysmnography (PSG)**
Complex Sleep Apnea

• Mix of Obstructive and Central events
  – Diagnostic sleep study w/ mostly obstructive events
  – Central events emerge or persist with CPAP
  – Some patients show improvement of central events after a short time on CPAP but others do not and continue to be sleepy or have insomnia
  – However it is difficult to predict responders vs non responders to CPAP.....
Can we predict which patients will respond to CPAP from the breathing pattern on a sleep study?
Loop Gain as a Component of Respiratory Control

**Stable**

- Disturbance
- Ventilation
- Response
- LG < 1

**Unstable**

- Disturbance
- Ventilation
- Response
- LG > 1

Loop gain (LG) = \( \frac{\text{Response}}{\text{Disturbance}} \)
$LG = \frac{\frac{2\pi}{2\pi DR - \sin(2\pi DR)}}{DR}$

Sands SA et al 2011
Study Aim

• Can duty ratio and loop gain be applied to patients with complex sleep apnea to predict responders versus non-responders to CPAP?
Methods

• Retrospective chart review

• Patients referred for evaluation of sleep disordered breathing were screened
  – January 2012- January 2013

• Demographic data and polysomnographic variables were collected (mean ± standard error)
  – Measured duty ratios and calculated loop gain from the clinical PSGs (on CPAP)

• Reviewed downloadable compliance data from CPAP device at 1 month
  – AHI, % of nights >4 hours use, hours/night
Methods

• ANOVA (analysis of variance) w/ Tukey post hoc test
  – Compared polysomnographic data (PSG) during
    • Baseline study, CPAP titration, and 1 month of CPAP use

• Duty Ratio, Loop Gain and Compliance data compared using paired T tests
  – CPAP “Responders and Non-Responders”
  – Non responder: residual AHI >5 events/h

• Simple regression to determine variance for the relationship between loop gain and residual AHI after CPAP.
3247 Sleep Studies

168 w/obst and central events on dx eval

32 pts w/ Complex Sleep Apnea

18 CPAP
4 BiPAP
7 ASV
3 no Rx

17 pt’s w/ 4 wk compliance downloads

9 responders
8 non responders
Sample PSG

[Graph showing physiological data with annotations for Ventilation Duration and Cycle Duration.]
### Demographics - Table 1

<table>
<thead>
<tr>
<th>Baseline Demographics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epworth</td>
<td>9.8 ± 0.8</td>
</tr>
<tr>
<td>AHI (events/h)</td>
<td>47 ± 4.9</td>
</tr>
<tr>
<td>Age (y)</td>
<td>61.2 ± 2.4</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>32.1 ± 1.1</td>
</tr>
<tr>
<td>Opiates (n)</td>
<td>2</td>
</tr>
<tr>
<td>Benzodiazepines (n)</td>
<td>3</td>
</tr>
<tr>
<td>CVA (n)</td>
<td>0</td>
</tr>
<tr>
<td>CHF (n)</td>
<td>2</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th></th>
<th>PSG baseline</th>
<th>CPAP titration</th>
<th>1 mo CPAP</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI events/h</td>
<td>47.0 ± 4.9* ¶</td>
<td>20.2 ± 3.0 *</td>
<td>6.4 ± 1.3 ¶</td>
<td>* ¶ p&lt; 0.001</td>
</tr>
<tr>
<td>OAHI</td>
<td>28.1 ± 4.7* ¶</td>
<td>6.2 ± 1.6 *</td>
<td>1.6 ± 0.7 ¶</td>
<td>* ¶ p&lt;0.001</td>
</tr>
<tr>
<td>CAHI</td>
<td>12.9 ± 2.6</td>
<td>11.6 ± 2.3</td>
<td>4.3 ± 1.5</td>
<td>p = 0.09</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th></th>
<th><strong>Responders (n=9)</strong></th>
<th><strong>Non Responders (n =8)</strong></th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty Ratio</td>
<td>0.58 ± 0.02</td>
<td>0.51 ± 0.03</td>
<td>0.038</td>
</tr>
<tr>
<td>Loop Gain</td>
<td>1.73 ± 0.16</td>
<td>2.02 ± 0.11</td>
<td>0.026</td>
</tr>
<tr>
<td>% time &gt;4 hours</td>
<td>77.4 ± 4.5</td>
<td>68.6 ± 11.5</td>
<td>0.47</td>
</tr>
<tr>
<td>CPAP hours/night</td>
<td>5.7 ± 0.23</td>
<td>4.9 ± 0.60</td>
<td>0.21</td>
</tr>
</tbody>
</table>

![Graph showing Duty Ratio vs Loop Gain](image.png)
Relationship Between Loop Gain and AHI

\[ r = 0.48 \quad r^2 = 0.23 \quad p = 0.04 \]
Conclusions

Loop gain (calculated from the duty cycle) is higher in CPAP non-responders (p= 0.026) in patients with complex sleep apnea

Clinical implications:
• Easy to measure from a PSG
• Early identification of CPAP non-responders
• More advanced/aggressive treatment of non-responders
Limitations

• Single Center study
  – Although prevalence data from prior studies corresponds to our study

• Short follow up

• Debate over clinical impact of complex sleep apnea

• Duty ratios
  – Equation presumes patent airway
Next Steps...

- Larger studies on loop gain/ duty ratios in complex sleep apnea
- Evaluation of other interventions to treat CPAP non-responders (ie oral appliances, adaptive servo devices)
References

• Javaheri S; Smith J; Chung E. The prevalence and natural history of complex sleep apnea. *J Clin Sleep Med* 2009;5(3):205-211

• Sands SA; Edwards BA; Kee K. Loop gain as a means to predict a positive airway pressure suppression of cheyne-stokes respiration in patients with heart failure. *Am J Respir Crit Care Med* 2011;184(9):1067-75