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Advanced Positive Airway Pressure Therapies
Disclosures

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Consulting: Elsevier, CareCore National

Chief Medical Liaison: Philips Respironics


I will not be discussing off-label uses
Learning Objectives

1. Recognize the indications and limitations of ASV and AVAPS
2. Learn when and how to use and adjust ASV and AVAPS settings
3. Understand the goals of ASV and AVAPS therapy
Rule No. 1

Know your patient.
# Polysomnography

<table>
<thead>
<tr>
<th>Mode</th>
<th>Total AHI</th>
<th>OA</th>
<th>OH</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>141</td>
<td>26</td>
<td>188</td>
<td>77</td>
</tr>
<tr>
<td>CPAP 5</td>
<td>137</td>
<td>14</td>
<td>53</td>
<td>33</td>
</tr>
<tr>
<td>CPAP 7</td>
<td>124</td>
<td>10</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>CPAP 9</td>
<td>46</td>
<td>1</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>CPAP 11</td>
<td>63</td>
<td>4</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>CPAP 11 + 2L</td>
<td>97</td>
<td>3</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>BPAP 15/11</td>
<td>68</td>
<td>5</td>
<td>4</td>
<td>31</td>
</tr>
</tbody>
</table>
Management of Complicated SA

Continue CPAP
- Lower setting
- Trial of higher setting
- Add O2

Stop CPAP, repeat PSG within a few days

Switch to BPAP ± O2 ± back-up rate

Switch to ASV
Patients

44, F, healthy, snoring, high altitude

68, M, heart failure, dyspnea

25, M, chronic pain, on narcotics
Patients

71, M, stroke, limited mobility

59, M, obese, snoring + apneas

69, F, snoring, insomnia, anxiety
Complicated Sleep Apnea

- CSA
- OSA
- Hypoventilation
## Syndrome Complexes

<table>
<thead>
<tr>
<th>Complex</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSA + CSA</td>
<td>Heart failure, Complex sleep apnea</td>
</tr>
<tr>
<td>OSA + Hypoventilation</td>
<td>COPD</td>
</tr>
<tr>
<td>CSA + OSA + Hypoventilation</td>
<td>Opioids, Neuromuscular disorder, Stroke</td>
</tr>
</tbody>
</table>
Rule No. 2

Understand respiratory physiology.
Pathophysiology

- Application of CPAP
- Reduction of PaCO2 below apneic threshold
- Development of CA
Pathophysiology

- Increase in PaCO2 above apneic threshold
- Cessation of CA / Resumption of breathing
- Hyperventilatory overshoot
Pathophysiology

- Reduction of PaCO2 below apneic threshold
- Development of CA
Changes in baroreflex sensitivity

Decreased work of breathing

Improved physiologic shunt
Heart Failure

OSA

CSA

- **Question:** Does overnight rostral fluid displacement and subsequent increase in neck circumference affect the severity of OSA and CSA in HF?

- **Subjects:** 57 subjects with HF (EF ≤ 45%)

- **Methods:** Prospective observational study
  - Subjects were divided into 2 groups:
    - Obstructive-dominant (≥ 50% of events are obstructive)
    - Central-dominant (> 50% of events are central)
  - Subjects with OSA received CPAP

• **Methods:**
  – Before and after PSG
    • Leg fluid volume (bio-electrical impedance)
    • Neck circumference
  – During PSG
    • TcCO2
Figure 1. In both the obstructive- (A) and central-dominant (B) groups, there were inverse exponential relationships between overnight changes in neck circumference and LFV.
Figure 2. In the obstructive-dominant group, there was no significant correlation between mean PtcCO₂ during sleep and overnight change in LFV (n=32; A). However, in the central-dominant group, there was a significant correlation between mean sleep PtcCO₂ and the overnight change in LFV (n=20; B).
Figure 4. Demonstration of a progressively greater reduction in LFV from patients with mild to no sleep apnea (M-NSA) (AHI <15; n=19) to OSA (AHI ≥15; n=21) to CSA (AHI ≥15; n=17).
Figure 3. Relationship between change in LFV and AHI in the obstructive- and central-dominant groups. The open circles and solid line represent the relationship between the AHI and the change in LFV in the obstructive-dominant group \[y=2.4 \cdot e^{(-0.011 \cdot x)}\]. The closed circles and dashed line represent the relationship between the AHI and the change in LFV in the central-dominant group \[y=5.1 \cdot e^{(-0.004 \cdot x)}\]. The slopes of these curves differed significantly \((P<0.001)\).
Shift in sleep apnoea type in heart failure patients in the CANPAP trial.

• **Question:** Does improvement in heart function during CPAP therapy of CSA in persons with HF lead to conversion of respiratory events into obstructive apneas?

• **Subjects:** 98 subjects with HF and CSA
  – LVEF: < 40%
  – AHl: ≥ 15 (> 50% central apneas)
Shift in sleep apnoea type in heart failure patients in the CANPAP trial.  

**Definitions:**
- Non-converter: > 50% of events remained central at follow-up
- Converter: ≥ 50% of events were obstructive at follow-up
<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonconversion group</th>
<th>Conversion group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects n</td>
<td>80</td>
<td>18</td>
<td>0.38</td>
</tr>
<tr>
<td>ΔNYHA class</td>
<td>0.0 (-0.1–0.2)</td>
<td>-0.1 (-0.5–2.3)</td>
<td>0.38</td>
</tr>
<tr>
<td>ΔLVEF %</td>
<td>-0.7 (-1.9–0.6)</td>
<td>2.8 (-0.4–6.0)</td>
<td>0.01</td>
</tr>
<tr>
<td>ΔCHFQ dyspnoea score</td>
<td>0.1 (0.5–1.2)</td>
<td>0.9 (0.2–1.6)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Data are presented as mean (95% CI), unless otherwise indicated. ΔNYHA: change in New York Heart Association; ΔLVEF: change in left ventricular ejection fraction; ΔCHFQ: change in Chronic Heart Failure Questionnaire score (>0.75 represents important change of moderate magnitude). p-values are for between group comparisons (ANCOVA).
ASV improved LVEF and BNP levels, and showed a tendency to improve NYHA class, in patients with severe heart failure.

** Improvement after ASV therapy  

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline 6 months</th>
<th>After ASV therapy</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left ventricular ejection fraction (LVEF) at 6 months</td>
<td>From 24.1 ± 5.6% to 35.2 ± 10.6%</td>
<td>P &lt; 0.0001</td>
<td></td>
</tr>
<tr>
<td>Brain natriuretic peptide (BNP) at 6 months</td>
<td>From 591 (273-993) to 142 (39-325) pg/ml</td>
<td>P = 0.002</td>
<td></td>
</tr>
<tr>
<td>New York Heart Association classification at 1 year (vs. LVEF ≥ 30% group)</td>
<td>50% vs. 29%</td>
<td>P = 0.07</td>
<td></td>
</tr>
<tr>
<td>Fatal cardiovascular events at 1 year (vs. LVEF ≥ 30% group)</td>
<td>11.9% vs. 5.9%</td>
<td>P = 0.36</td>
<td></td>
</tr>
</tbody>
</table>

Baseline LVEF < 30%

**Safety and efficacy of adaptive servo-ventilation in patients with severe systolic heart failure.** Takama N, Kurabayashi M. *J Cardiol.* 2013 Dec 25.
Complex Sleep Apnea

Development or persistence of CSA or CSR with acute CPAP therapy in patients with predominantly OA or MA during the initial diagnostic study

CPAP successfully eliminates OAH events but AHI remain elevated and sleep disruption persists due to CSA or CSR
Alternative Names

Many consider CompSA as a clinical subtype of CSA

- CPAP-emergent CSA
- CPAP-persistent CSA
- Complicated sleep disordered breathing
Clinical Features

<table>
<thead>
<tr>
<th>Compared to OSA</th>
<th>Compared to CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly lower BMI</td>
<td>Higher BMI</td>
</tr>
<tr>
<td></td>
<td>More frequent snoring</td>
</tr>
<tr>
<td></td>
<td>Less HF</td>
</tr>
<tr>
<td></td>
<td>Higher LVEF</td>
</tr>
<tr>
<td>Author/ Site (year)</td>
<td>n</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Morgenthaler Rochester, USA (06)</td>
<td>223</td>
</tr>
<tr>
<td>Derniaka Oklahoma, USA (06)</td>
<td>116</td>
</tr>
<tr>
<td>Lehman Adelaide, Australia (07)</td>
<td>99</td>
</tr>
<tr>
<td>Javaheri Cincinnati, USA (09)</td>
<td>1286</td>
</tr>
<tr>
<td>Endo Japan (07)</td>
<td>1232</td>
</tr>
<tr>
<td>Yaegashi Japan (09)</td>
<td>297</td>
</tr>
</tbody>
</table>
# Complex Sleep Apnea

## Differential Diagnosis

<table>
<thead>
<tr>
<th>NREM periodic breathing</th>
<th>Variable SRBD - supine-position OA and non-supine CA</th>
<th>Acute development of anxiety with post-hyperventilatory hypocapnic CA</th>
</tr>
</thead>
</table>
Complex Sleep Apnea

Transitional

Transitory

Transient
Rule No. 3

Select the appropriate therapy.
Advanced PAP Modalities

- Periodic respiration
  - ASV
- Inadequate ventilation
  - AVAPS
## Advanced PAP Modalities

<table>
<thead>
<tr>
<th>Periodic respiration</th>
<th>Inadequate ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheyne Stokes respiration</td>
<td>Advanced COPD</td>
</tr>
<tr>
<td>Complex sleep apnea</td>
<td>Obesity hypoventilation syndrome</td>
</tr>
</tbody>
</table>
Rule No. 4

Learn how to operate each device.
## Servo ventilation

<table>
<thead>
<tr>
<th></th>
<th>BiPAP</th>
<th>VPAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>Peak flow</td>
<td>Minute ventilation</td>
</tr>
<tr>
<td>EPAP</td>
<td>Automatic</td>
<td>Manual</td>
</tr>
<tr>
<td>EPAP</td>
<td>4-25 cmH20</td>
<td>4-15 cmH20</td>
</tr>
<tr>
<td>PS [min]</td>
<td>0 cmH20</td>
<td>3 cmH20</td>
</tr>
<tr>
<td>Rate [default]</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>
Servo ventilation

- **Obstructive events**: Increases EPAP
- **Hypopneas**: Increases inspiratory PS
- **Hyperpneas/hyperventilation**: Decreases inspiratory PS
- **Impending apneas**: Back up rate
Servo ventilation

- Hyperpnea
- Hypopnea
- Hyperpnea

PS

PS

PS
Rule No. 5

Turn the machine on.
## BiPAP AutoSV Advanced

<table>
<thead>
<tr>
<th>Setting</th>
<th>Initial settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPAPmin</td>
<td>4 cmH2O</td>
</tr>
<tr>
<td>EPAPmax</td>
<td>15</td>
</tr>
<tr>
<td>Psmin</td>
<td>0</td>
</tr>
<tr>
<td>Psmax</td>
<td>20</td>
</tr>
<tr>
<td>Max pressure</td>
<td>25</td>
</tr>
<tr>
<td>Rate</td>
<td>Auto</td>
</tr>
<tr>
<td>Biflex</td>
<td>+/-</td>
</tr>
</tbody>
</table>
BiPAP AutoSV Advanced

Target: 4-minute moving average of breath-by-breath peak flow

Settings:
- Automatic EPAP
- Automatic PS
- Automatic back-up rate
Rule No. 6

Be patient.
Time for the patient to adapt to the machine.

Time for the machine to adapt to the patient.
Rule No. 7

Make proper adjustments to enhance patient comfort.
If patient is unable to fall asleep

Breathing discomfort
- Adjust Biflex

If UA obstruction present
- Increase EPAPmin by 1-2 cmH2O

If UA obstruction absent
- Increase PSmin by 1-2 cmH2O
Rule No. 8

Prioritize goals.
Patient

70, M, with snoring and EDS

- Lifelong smoker, COPD
- Poorly controlled CHF
- Morbidly obese with OHS
- On opiates for chronic back pain
- Taking sedatives for insomnia
UA closure
- EPAP

CSA/Hypoventilation
- Pressure support
- Rate

Hypoxia
- EPAP, PS
- O2
During the night

If UA obstruction present

- Increase EPAPmin

If central apneas persist

- Increase PSmax or set rate to 8-10
Rule No. 9

Know when and why you failed.
Define “failure”

Reevaluate for underlying comorbidities
  - Maximize therapy
  - Reduce opioids

Switch to “other” ASV device

Use the right tools
<table>
<thead>
<tr>
<th>Hypercapnic</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Severe COPD</td>
</tr>
<tr>
<td>- Obesity hypoventilation syndromes</td>
</tr>
<tr>
<td>- Neuromuscular disorders</td>
</tr>
<tr>
<td>- Chronic use of long-acting opioids</td>
</tr>
</tbody>
</table>
Sleep-Related Hypoventilation

PaCO$_2$, PetCO$_2$ or PtcCO$_2$

- Exceeds 55 mmHg for $\geq 10$ minutes, or
- Rises $\geq 10$ mmHg above awake supine level to a value $> 50$ mmHg for $\geq 10$ minutes during sleep
BiPAP with AVAPS

Bi-level with Average Volume Assured Pressure Support (AVAPS)

- Maintains a stable tidal volume
- Automatically adjusts PS between IPAPmin and IPAPmax
# BiPAP with AVAPS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPAP</td>
<td>4 cmH2O</td>
</tr>
<tr>
<td>IPAPmin</td>
<td>8</td>
</tr>
<tr>
<td>IPAPmax</td>
<td>25</td>
</tr>
<tr>
<td>Rate</td>
<td>8-10 bpm</td>
</tr>
<tr>
<td>I-time</td>
<td>1.5 sec</td>
</tr>
<tr>
<td>Rise time</td>
<td>2-3</td>
</tr>
<tr>
<td>Tidal volume</td>
<td>Adjust to patient comfort to allow sleep onset</td>
</tr>
</tbody>
</table>
BiPAP with AVAPS

Courtesy of Philips Respironics
BiPAP with AVAPS

**Starting tidal volume**

- Ideal body weight – 8 ml/kg
- Patient comfort
- As suggested by physician
During the night

If obstructive events persist
- Increase EPAP and IPAPmin (keep PS)

If hypoventilation persists
- Increase PS or rate

If hypoxemia is present
- Increase EPAP, PS or rate; add O2
## BiPAP with AVAPS

### Table 1: Clinical studies on target volume during pressure-preset ventilation

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Design</th>
<th>Cohort</th>
<th>Target volume setting</th>
<th>Main target volume outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storre et al(^7) †</td>
<td>2006</td>
<td>6-week cross-over RCT (n=10)</td>
<td>OHS‡</td>
<td>7 ml/kg IBW (n=5), 10 ml/kg IBW (n=5)</td>
<td>Greater reduction in nocturnal PtcCO(_2)</td>
</tr>
<tr>
<td>Janssens et al(^10) †</td>
<td>2009</td>
<td>1-day cross-over RCT (n=12)</td>
<td>OHS¶</td>
<td>7.5±0.8 ml/kg body weight</td>
<td>Greater reduction in nocturnal PtcCO(_2)</td>
</tr>
<tr>
<td>Ambrogio et al(^11) †</td>
<td>2009</td>
<td>1-day cross-over RCT (n=28)</td>
<td>Mixed¶</td>
<td>8 ml/kg IBW or 110% of baseline VT</td>
<td>Greater nocturnal minute volume</td>
</tr>
<tr>
<td>Crisafulli et al(^12) †</td>
<td>2009</td>
<td>5-day cross-over RCT (n=9)</td>
<td>COPD‡</td>
<td>8 ml/kg IBW</td>
<td>Comparable improvements in morning PaCO(_2)</td>
</tr>
<tr>
<td>Oscroft et al(^13) §</td>
<td>2010</td>
<td>8-week cross-over RCT (n=24)</td>
<td>COPD¶</td>
<td>11.0±3.9 l/min (minute volume)</td>
<td>Comparable effects on:</td>
</tr>
<tr>
<td>Murphy et al(^14) †</td>
<td>2012</td>
<td>3-month RCT (n=46)</td>
<td>OHS‡</td>
<td>Individual adjustments aimed at achieving control of nocturnal hypoventilation while abolishing obstructive events</td>
<td>Comparable effects on:</td>
</tr>
</tbody>
</table>

Windisch and Storre. Thorax 2012
BiPAP with AVAPS

10 patients with OHS, failed CPAP

Storre JH et al. CHEST 2006
Rule 10.

Monitor the patient.
## Summary of Key Points

<table>
<thead>
<tr>
<th>Key Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know your patient.</td>
</tr>
<tr>
<td>Understand respiratory physiology.</td>
</tr>
<tr>
<td>Select the appropriate therapy.</td>
</tr>
<tr>
<td>Learn how to operate each device.</td>
</tr>
<tr>
<td>Turn the machine on.</td>
</tr>
<tr>
<td>Be patient.</td>
</tr>
<tr>
<td>Make proper adjustments to enhance patient comfort.</td>
</tr>
<tr>
<td>Prioritize goals.</td>
</tr>
<tr>
<td>Know when and why you failed.</td>
</tr>
<tr>
<td>Monitor the patient.</td>
</tr>
</tbody>
</table>
Summary

The ASV Song

Uga chaka uga uga
Uga chaka uga uga
Uga chaka uga uga
(Please repeat ......)
Part 1

You can stop these apneas - Cheyne Stokes and central
ASV will help your patients with heart failure
When you use it during study nights
You’ll realize everything’s alright
Try... servo ventilation
Might reduce readmission
Enhance ejection fraction
Last Part

As you choose your patients, keep this on your mind
It works on complex apneas, most of the time
Through the sleep nights, if upper airways close
Increase EPAP, and make it comfortable
Add... servo ventilation
Control respiration
Improve sleep consolidation....
Questions