Central Sleep Apnea and ASV: What should I know as a tech?

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1. I do not have any relationships with any entities *producing, marketing, re-selling, or distributing* health care goods or services consumed by, or used on, patients, **OR**

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

   1. 
   2. 
   3.
Objectives

1) Understand the diagnosis and treatment strategies for central sleep apnea (CSA)
2) Understand the different forms of central sleep apnea
3) Describe how Adaptive/Automatic Servo-Ventilation (ASV) works and treats central sleep apnea
4) Describe the appropriate indications to use ASV
General Principles for Diagnosis

1) Must have clinical symptoms or medical comorbidities to make diagnosis
   - Sleepiness, insomnia, snoring, apneas, awakening with SOB
   - A-fib, CHF, or neurological disorder (such as stroke, MS)
2) Central AHI >5
3) Central apneas and hypopneas >50% of total AHI
4) Not better explained by another sleep disorder
Sleep Apnea and Comorbidities

- 86% of obese type 2 diabetics suffer from sleep apnea
- 65-70% of stroke patients have Sleep Disordered Breathing (SDB)

### Prevalence of Sleep Apnea in Comorbidities

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug-Resistant Hypertension</td>
<td>83%</td>
</tr>
<tr>
<td>Obesity</td>
<td>77%</td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>76%</td>
</tr>
<tr>
<td>Pacemakers</td>
<td>59%</td>
</tr>
<tr>
<td>Atrial Fibrillation</td>
<td>49%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>48%</td>
</tr>
<tr>
<td>All Hypertension*</td>
<td>37%</td>
</tr>
<tr>
<td>Coronary Artery Disease*</td>
<td>30%</td>
</tr>
</tbody>
</table>

*Male subjects only
Prevalence of CSA

- 6.5–15% of OSA patients suffer from complex sleep apnea syndrome
- 18% of heart failure patients with OSA develop complex sleep apnea during CPAP titration
- 30% of heart failure patients have Cheyne–Stokes Respiration (CSR)
- 75% of patients on opioids for chronic pain have an AHI > 5
CSA Pathophysiology

- CO₂ falls below apneic threshold
- CO₂ does not rise as much during sleep
  - CO₂ levels during sleep closer to apneic threshold
- Arousals and transitional sleep lead to hyperventilation
- Increased responsiveness of chemoreceptors
  - Heightened ventilatory responses to arousals and CO₂ changes
  - Hyperventilation and lowering of CO₂
  - Increased sympathetic tone
  - High loop gain
CSA Pathophysiology (cont.)

- Delay in circulation time
  - Leads to longer cycle length in CSB
- Pulmonary irritant receptor stimulation
  - Pulmonary congestion
    - Supine Position: ↑ cardiac filling pressures
  - CPAP over-titration
- Central apneas usually increase through the night
  - Due to increased pulmonary congestion during the night
- Mild airway obstruction possibly contributes
Over-titration of CPAP

Supine Position
- ↑ cardiac filling pressures
- Upper airway narrowing
Central Sleep Apnea Classification

- With Cheyne-Stokes Breathing (CSB)
- Due to a medical disorder without Cheyne-Stokes
- Due to high altitude periodic breathing
- Due to medication or substance
- Primary (Idiopathic)
- Primary of Infancy or prematurity
- Treatment-Emergent (Complex SA)
CSA with Cheyne-Stokes

- Crescendo-decrescendo pattern
- Cycle length >40 seconds (usually closer to 60 seconds)
- Systolic CHF – longer cycle length
- May be a delay in desaturations – adjust when scoring
- Arousals at top of hyperpnea
Cheyne-Stokes, Delayed Desats
Timing of arousals CSB vs other

Eckert,
Chest 2007
CSA with Cheyne-Stokes

- Less commonly complain of daytime sleepiness
- Often combination OSA and CSA, and CSA becomes more prominent after CPAP initiated
- Usually absent or minimal in REM, minimal in N3
- May be seen in 25-40% of patients with chronic CHF and 26-50% of those acutely following stroke
- Associated with A-fib, renal failure, daytime hypocapnia
CSA from Medical Disorder

- Usually brainstem lesion
- Stroke
  - May continue in 7% long term
  - Can get Cheyne-Stokes in bilateral lesions
- Multiple Sclerosis
  - Brainstem plaques
- Tumor
- Chiari Malformation
- Multiple System Atrophy
CSA and Stroke
Medullary Astrocytoma
CSA from Medication or Substance

- Suppresses respiratory drive
- Opioids – Methadone, long acting opioids, Suboxone, fentanyl patches
  - Dose dependent
- May improve somewhat over time
- May see ataxic breathing (Biot’s respirations)
- Can also cause hypoventilation and OSA
- Sleepiness often caused by substance, not CSA
Figure 1—Rate ratio for morphine dose equivalent and obstructive apnea, central apnea, and hypopnea indexes; all adjusted for weight, sex, and age. REM refers to rapid eye movement sleep; NREM, non-rapid eye movement sleep.
Primary (Idiopathic) CSA

- Usually have low normal CO₂ levels at baseline
- Heightened ventilatory responses to arousals and CO₂ changes – chemoreceptors more responsive
  - High loop gain
- Frequent arousals worsen central apnea - usually lower arousal threshold
Treatment-Emergent (complex) CSA

- Obstructive or mixed events on baseline, then predominantly central events on titration
- Often resolved in REM and N3, prominent in N1-N2.
  - Look in REM to see what pressure treats obstruction
- Prevalence: 2-20% on first or second night with CPAP
  - Seen in 15% of SDB population in academic sleep center
  - Seen in 18% of CHF patients
  - Closer to 2% have persistent CSA on chronic CPAP therapy
- About 50% of complex SA patients never have good clinical response to CPAP
  - Residual sleepiness, insomnia, arousals
  - CPAP intolerance: “tearing off mask”

Morgenthaler et al, *Sleep*, 2006
Treatment-Emergent (complex) CSA

- Often low arousal threshold
- Reducing upper airway resistance brings out centrals
- Over-titration can bring out central apneas
- Under-titration can lead to events and arousals which lead to central events
- Bi-PAP often makes it worse
- Arousals from mask leak
- Split night studies are more commonly associated
- Unclear how much will resolve with time
Treatment Options for CSA

- ASV
- Supplemental oxygen
  - Trouble with reimbursement
- BiPAP with fixed backup rate (ST)
  - Usually only if ASV and oxygen not effective
- Hypnotics – decrease arousals
- Positional therapy
- ? Acetazolamide (Diamox)
- Opioid induced – withdrawal of opioids
When do I use ASV?
ASV Indications – AASM Practice Parameters

- Clearly for CSA in CHF
  - Initial treatment still optimization of medical therapy and CPAP
  - No long term data
- Short term follow up shows improved outcomes
  - Improved survival
  - Improved cardiac function
  - Decreased cardiac events
  - Improved exercise tolerance & quality of life
- Increased cost
ASV Indications (cont.)

- Insufficient evidence in opioid related SA, complex SA or primary CSA
  - Barely any outcomes studies for these
  - Studies on complex SA show good effectiveness of ASV
  - Mixed studies on effectiveness in opioid related CSA
    - Recent study showed good long term efficacy and compliance
      - Mean 25 month f/u, usage 5.1 hrs, AHI 3.3, ESS decrease by 2
      - Controversial to use in opioid CSA without hypoxemia or desats

CSA in Opioid Use

ASV Indications

- Do not use if hypoventilation
  - Targets patient’s own ventilation, which is inadequate in patients with hypoventilation
When To Switch To ASV

- Very severe central apnea on initial titration
  - To the point you feel may cause harm to patient if sent home on CPAP or BiPAP
  - If patient cannot tolerate CPAP or BiPAP
- If after 1-2 month follow up, high suspicion for persistent central sleep apnea
  - High AHI on download
  - Patient having persistent insomnia, arousals or daytime sleepiness, despite adequate compliance
CSA CMS Guidelines

- MUST be aware of this if switching patients to ASV in middle of study – must meet criteria
  - Need to calculate central AHI if possible
- Central AHI >5
  - Can be on titration if complex sleep apnea
- Central AHI >50% of total AHI
- Symptoms of excessive sleepiness or disrupted sleep
- CPAP has been ruled out as effective therapy
Transplant Free Survival in CHF Patients With CSA on CPAP

CPAP responders, n = 57
AHI at 3 months < 15/hr, mean=6.5

Control, n = 110
AHI at 3 months ≥ 15/hr, mean=36

CPAP non-responders, n = 43
AHI at 3 months ≥ 15/hr, mean=35

*versus control: HR=0.36, p=0.040

Artz, Circ 2007 CANPAP
Effect of ASV on Survival in CHF

Takama and Kurabayashi, Circulation J, 2012
How does ASV work???
ASV in once sentence:
Dynamically adjusts pressure support and respiratory rate to stabilize patient’s breathing
Different Machines Work Differently

- Resprironics BiPAP Auto SV Advanced System One
  - Peak flow measurement – 95% target
  - 4 minute moving window
  - Auto adjusting EPAP
    - Responds to OA, OH, flow limit, snore
  - Biflex
  - EPAP decreases with excessive leak

- ResMed VPAP Adapt Auto
  - Minute ventilation – 90% target
  - 3 minute moving window
  - Now auto adjusting EPAP (ASV auto mode)
    - Responds to OA, flow limit & snore
  - “Easy-breathe” – syncs with patients breathing
  - no EPR available
  - BR increases with excessive leak
On a breath by breath basis peak flow is captured

Peak flow is monitored over a moving 4 minute window

As 1 breath is added, the initial breath falls off

At every point within this 4 minute period an *Average Peak Flow* is calculated

The *Peak flow target* is established around that average and is based on the patient’s needs
VPAP Adapt Estimates Minute Ventilation

- Targets 90% of this calculation
- It averages over a 3 minute moving window
- Peak flow may be the same although minute ventilation is different
VPAP Adapt turned ON

Patient Flow

VPAP Adapt Pressure

APNEA APNEA

A decrease in ventilation is rapidly treated by increasing Pressure Support

Pressure Support decreases when normal breathing (or hyperventilation) resumes

VPAP Adapt rapidly stabilizes breathing by increasing Pressure Support in response to hypoventilation

The minimal Pressure Support during normal breathing or hyperventilation prevents over ventilation and hypcapnia

VPAP Adapt turned OFF

HYROPNEA APNEA
BiPAP Auto SV Advanced – Auto EPAP

- Increase 1 cm after 2 events (OA or OH) or 3 snoring events
  - Will wait at least 2 minutes before increasing EPAP again
- Looks every 5 minutes at flow signal and increases EPAP by 1 cm to see if makes a difference in flow limitation (Pro Active Analysis)

**Sophisticated Three Layered Algorithm:**

- **Primary Function:**
  - *Pro Active Analysis*

- **Safety Net:**
  - Apnea
  - Hypopnea
  - Flow Limitation
  - Vibratory Snore

- **Leak Tolerance**
Event classified as an **Obstructed Airway Apnea**

EPAP pressure increased (after 2-OA’s)
VPAP Adapt Auto EPAP Mode
Auto SV Advanced System One Parameters

- EPAPmin: 4-25 cm H2O
- EPAPmax: 4-25 cm H2O
- PSmin: 0-21 cmH2O (default 0)
- PSmax: 0-21 cm H2O (PS min to IPAP 25)
- Max pressure: 25 cm H2O
- Rate: Auto (8-15), or fixed (4 – 30 BPM)
- Timed Insp (if rate fixed): 0.5 – 3.0 sec (default 1.2 secs)
  - Consider shorter inspiratory time for COPD patients
- Rise: 1 – 6 (100 – 600ms) – longer rise may help with comfort
- Bi-Flex: set to patient comfort (0-3)

Figure 3-2 Triggering and Cycling when the Back-Up Rate is Off
ResMed VPAP Adapt Auto Parameters

- **EPAPmin:** 4-15 cm H2O
- **EPAPmax:** 4-15 cm H2O
- **PSmin:** 0-6 cm H2O (default 3) – *previously was 3-6*
  - Default is 3, mainly for comfort, to assist with work of breathing
- **PSmax:** 5-20 cm H2O (PS min to IPAP 25)
- **Max pressure:** 25 cm H2O
- **Rate:** Auto (15)
  - 15 is default, but adjusts down as low as 10 if patient meeting minute ventilation requirements in last 4-6 breaths
- **Ramp time:** 0-45 min
- Can’t input Inspiratory time or Rise time
ASV Effectiveness

- Both Machines very effective in reducing AHI in CSA
ASV Titrations

- CPAP and BiPAP titrations: only need to worry about EPAP and fixed pressure support for BiPAP adjustments
- ASV has more settings to adjust, however, adjustments are not usually as frequent as CPAP and BiPAP
Auto SV Advanced System One Protocol

- Usually start a few cm below CPAP pressure which eliminated obstruction on the CPAP or BiPAP titration

Set mode to BiPAP autoSV Advanced

- Establish initial settings as indicated bellow or as ordered by physician
- Ensure proper mask fit to allow algorithm to work effectively
- Have patient breathe on autoSV Advanced at basic settings below
- Adjust EPAP\textsubscript{min} Bi-Flex and PS\textsubscript{min} settings to patient comfort

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPAP\textsubscript{min}</td>
<td>4 cm H\textsubscript{2}O*</td>
<td>Max Pressure</td>
<td>25 cm H\textsubscript{2}O</td>
</tr>
<tr>
<td>EPAP\textsubscript{max}</td>
<td>15 cm H\textsubscript{2}O</td>
<td>Rate</td>
<td>auto</td>
</tr>
<tr>
<td>PS\textsubscript{min}</td>
<td>0 cm H\textsubscript{2}O</td>
<td>Bi-Flex</td>
<td>to patient</td>
</tr>
<tr>
<td>PS\textsubscript{max}</td>
<td>20 cm H\textsubscript{2}O</td>
<td></td>
<td>comfort</td>
</tr>
</tbody>
</table>

*if patient has known CPAP pressure of < 10 set EPAP\textsubscript{min} at 4 cm H\textsubscript{2}O or patient comfort

*If patient has known CPAP pressure of > 10 set EPAP\textsubscript{min} at 6-8 cm H\textsubscript{2}O or patient comfort
- ASV is a SLOW titration – often recommended to wait 20 minutes before a change, but use your best judgment.
- Always keep an eye on what the machine is doing.
VPAP ASV older titration guide

**EEP:**

If patient has obstructive events increase EEP by 1 cmH$_2$O every 20-30 minutes until obstructive events are eliminated.

**Min Pressure Support:**

If patient has residual hypoventilation, residual snore (snore without scoreable event), oxygen desaturations w/o correlating obstructive event, increase Min Pressure Support by 1 cmH$_2$O every 30 minutes until events are eliminated.

**Max Pressure Support:**

Max Pressure Support should remain at default setting of 15 cmH$_2$O unless spontaneous arousals are noted without a correlating respiratory event or limb movements, in that event decrease Max Pressure Support by 1 cmH$_2$O every 20 minutes until arousals are eliminated.
Start therapy at default settings and observe patient for 20-40 minutes

- Is patient having events? NO
  - Are events obstructive? NO
    - Increase EEP by 1 cm H₂O every 20 minutes until events are gone
  - Are there central events? YES
    - Increase max PS as needed to allow device to meet target ventilation. If PS level is maxing out, check for leak.
- Are events obstructive? YES
  - Observe patient. Document response to therapy.
  - Excessive leak
    - Leak is greater than 24 L/min
      - Adjust or change mask until leak fixed
  - Obstructive events eliminated? Any obstructive apneas, hypopneas or RERAs?
    - Increase EPAP by 1 cm H₂O every 20 minutes until obstructive events are eliminated
My Thoughts on ASV Titrations

- Usually we are titrating based on hypopneas
- Always watch for high leaks, very common! – adjust mask
- Flow limitation, paradoxical breathing, snoring: ↑ min EPAP
  - Keep an eye on what machine is automatically doing with EPAP and PS: watch the pressure line
- If none of above and breathing looks periodic, centrals occurring or PS maxing out: ↑ Max PS
- If still ambiguous hypopneas:
  - Try backup rate: May be helpful for opioid related CSA
  - Try increasing Min PS: can help with patient comfort, decrease arousals
  - Consider adding supplement O2 (especially if low sats)
- See how they look in the lateral position
- If arousals very frequent – try hypnotic
Watch for Breath Stacking

- Patient below had a sleeping baseline rate of 9-10 bpm
- Switched to a backup rate of 12 and started breath stacking
- Need to pick rate 1-2 below baseline rate.
ASV Titrations (cont.)

- If pressure intolerance – patient complains, frequent arousals:
  - Increase Min PS
  - Try adjusting rise time or Biflex (on Respironics)
  - Consider decrease Max PS (as long as central events controlled)
- O2 sats low despite events being controlled: ↑ Min PS, consider O2
  - Be careful: This may be a sign of hypoventilation or lung disease
  - If obstructive lung disease: backup rate with decreased I-time
  - If restrictive lung disease: backup rate with increased I-time
- If all else fails:
  - Consider switching brand of ASV machine or trying BiPAP ST
  - Consider CPAP at lower pressures with supplemental O2 +/- hypnotics
  - Consider trying AVAPS (if suspicion for hypoventilation)
    - AVAPS not effective for CSB or periodic breathing
Note position and sleep stage differences

Central Apneas
Obstructive Apneas
Hypopneas

ASV started
Min EPAP increased

Hypnogram
Respiratory Events
Leak Position
PLM
SPO2
Obstructive apneas on baseline

Central apneas on CPAP (absent in REM)

Down titration of CPAP did not improve centrals
Obstructive & central apneas on CPAP

Central apneas on BiPAP

ASV started
With CPAP
With ASV
ASV Follow Up

• Goals:
  • improve arousals, daytime sleepiness
    • No good evidence on this
  • Improve cardiac function & survival in CHF patients

• Problems
  • Residual AHI
    • ? Obstructive vs Central
    • Frequent arousals/insomnia – try hypnotic
    • High leaks
  • Pressure intolerance - try ramp, Biflex, adjust rise time, or decrease pressure
  • High leaks – mask adjustment, pressure decrease
  • Residual sleepiness – look for other causes
**Therapy Data Summary - All Data**

### Compliance Summary

<table>
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<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Date Range</td>
<td>5/27/2009 - 7/22/2009 (57 days)</td>
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<tr>
<td>Days with Device Usage</td>
<td>42 days</td>
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<tr>
<td>Days without Device Usage</td>
<td>15 days</td>
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<tr>
<td>Percent Days with Device Usage</td>
<td>73.7%</td>
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<td>Cumulative Usage</td>
<td>11 days 15 hrs. 31 mins. 39 secs.</td>
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<td>Maximum Usage (1 Day)</td>
<td>9 hrs. 47 mins. 7 secs.</td>
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<td>Average Usage (All Days)</td>
<td>4 hrs. 54 mins. 14 secs.</td>
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<tr>
<td>Average Usage (Days Used)</td>
<td>6 hrs. 39 mins. 19 secs.</td>
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<tr>
<td>Minimum Usage (1 Day)</td>
<td>2 hrs. 42 mins. 55 secs.</td>
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<td>Percent of Days with Usage &gt;= 4 Hours</td>
<td>63.2%</td>
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<tr>
<td>Percent of Days with Usage &lt; 4 Hours</td>
<td>36.8%</td>
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<tr>
<td>Total Blower Time</td>
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### BiPAP autoSV Advanced Summary

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<th>Description</th>
<th>Value</th>
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<tr>
<td>Average Device EPAP Pressure &lt;= 90% of Time</td>
<td>11.9 cmH2O</td>
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<tr>
<td>Average Percent of Night In Periodic Breathing</td>
<td>0.0%</td>
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<tr>
<td>Average Time In Large Leak Per Day</td>
<td>1 mins. 41 secs.</td>
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<tr>
<td>Average Breath Rate</td>
<td>12.1 bpm</td>
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<td>Average Minute Vent</td>
<td>7.3</td>
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<tr>
<td>Average AHI</td>
<td>10.9</td>
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</tbody>
</table>

### Settings

- Min EPAP: 10.0
- Max EPAP: 15.0
- Min Pressure Support: 0.0
- Max Pressure Support: 10.0
- Max Pressure: 30.0
- Backup Rate: Auto
- Flex Setting: 1
Daily Details
7/14/2009 1:34 AM - 7/14/2009 8:26 AM

Pressure (cmH2O)

Patient Triggered Breaths (%)

Sleep Therapy Flags

Avg PS
3.0

90% EPAP
11.0

Avg % Patient Triggered Breaths
88.8

PB
0 % of night

Indices
CA: 1.0
OA: 1.0
H: 6.0
FL: 1.0
VS: 2.0
AHI: 8.0
High Leak Causing Increase AHI

AHI better when leak better
Summary/Conclusions

- CSA is a prevalent disorder in certain populations
- Can lead to worse outcomes in CHF, but not much data on long term outcomes in other forms of CSA
- ASV often first line of treatment, improves outcomes in CHF
- Switch to ASV for severe centrals or poor clinical response to CPAP/BiPAP on follow up
- The 2 main ASV machines differ in mechanism, but both achieve good results
- ASV titration is SLOW
  - Always watch for leaks
  - Watch patient and machine closely to determine next step in titration
- Watch for residual symptoms or elevated AHI on follow up
Questions??
Art Prize Beer Tour – Lets Go!!
References

- ResMed ASV slides – including titration protocols
- Respironics ASV slides – including titration protocols
- Westhoff, et al. Sleep Breath On line 2/25/11
- Oldenburg et al. SLEEP 2012 Poster and Abstract.
- Javaheri, S. et. al, ERS 2009, Session #52