EFFECT OF SLEEP-DISORDERED BREATHING ON CARDIOVASCULAR HEALTH

- No relevant conflict of interest pertaining to this topic.

- Served as primary investigator with: Novartis, GSK, AstraZeneca, Bayer, Merck, FerRe, Pearl pharmaceutical, Shinogi, Jazz pharmaceutical, Theravance, Sunovion
CASE

- 59 y.o. female with history of atrial fibrillation, asthma, Obesity, tobacco use disorder
- Admitted on 10/3/2021 following presentation to ANW emergency department for evaluation of worsening shortness of breath.
- Suffering intermittent shortness of breath for several months, but worse the last several weeks.
- She quit smoking 2/2021. She reports having multiple steroid bursts in the last few months and reports that she usually feels better when she is on the steroids but that symptoms worsen again after stopping them.
- She was also given a course of cefdinir by her primary care physician 8/2021.

- Patient reports that she has gained approximately 100 pounds in the last 2 years after switching jobs.
- Reports lower extremity edema, using as needed Lasix
- Feels that when her edema is better, her breathing is also better.
- She has a history of severe obstructive sleep apnea but does not use CPAP because she reports it previously caused her to have facial cellulitis and has had difficulty with the fit of nasal masks, although she admits she only tried one mask.
- Patient reports a history of atrial fibrillation but was previously told that anticoagulation was not indicated given her risk factors???
• She was on diltiazem a few years ago when she was diagnosed with atrial fibrillation but had lower extremity edema and reports it made her thinking less clear so stopped it.

• She is hypoxic requiring BIPAP

**EXAM**

• BP 120/92 | Pulse (l) 163 | Temp 99.6 °F (37.6 °C) | Resp (l) 26 | Ht 1.657 m (5'5.25") | Wt (l) 138.3 kg (305 lb) | LMP 01/28/2011 | SpO2 98% (on 60% BiPAP) | BMI 50.37 kg/m² Temp (24hrs), Avg:99.6 °F (37.6 °C), Min:99.6 °F (37.6 °C), Max:99.6 °F (37.6 °C)

• Respiratory: Expiratory wheeze right base and bibasilar crackles Tachypnea mild distress

• Cardiovascular: Irregularly irregular HRs 120-160s, no murmurs appreciated

• Gastrointestinal: Protuberant, Normal BS, abdomen soft, obese, non-distended, non-tender

• Extremities: 2+ pitting edema bilaterally distal to the knees
Chest Radiograph 10/3
No acute cardiopulmonary disease. Minor interstitial prominence diffusely not greatly changed. Heart size is upper normal. No bone finding of significance.

- ECG interpretation
  Atrial fibrillation with rapid ventricular response
  Septal infarct, age undetermined
  Abnormal ECG
CT CHEST 10/3

IMPRESSION:

ECHOCARDIOGRAM

Final Impressions:
1. Technically limited exam.
2. Mild to moderately increased LV size, mildly increased wall thickness, mildly reduced global systolic function with an estimated EF of 40 - 45%.
3. Right ventricular cavity size is mildly enlarged; global systolic RV function is mildly reduced.
4. Severely enlarged left atrium.
5. Moderate posteriorly directed mitral regurgitation.
7. The inferior vena cava is dilated, respiratory size variation less than 50%.

HOSPITAL COURSE

Cardiology and Pulmonary consulted.
The patient was managed with diltiazem drip and IV furosemide to achieve euvoeemia.

Started steroid taper with optimization of inhalers with pulmonary follow up.
patient finally agreed to DOAC, although she would frequently try to drive her own cares.
Cardiology follow up scheduled
Otherwise had improvement in HR control and patient felt to be euvolemic.
She felt much improved symptomatically. She was discharged to home in stable condition
with recommendation for outpatient PT (which she declined).
Was agreeable to undergo PAP titration study (scheduled but missed appointment
November 5)
EFFECT OF SLEEP-DISORDERED BREATHING ON CARDIOVASCULAR HEALTH

- Obstructive sleep apnea (OSA) has been associated with many different forms of CVD including hypertension, stroke, HF, coronary artery disease, and atrial fibrillation (AF).
- Adults with OSA not only have an increased risk of developing comorbid CVD but also have worse outcomes related to CVD. OSA is highly prevalent, estimated to affect 24% of men and 9-15% of women in the general population and 40% to 60% of patients with CVD.
- Furthermore, the prevalence is increasing, with these figures representing a 30% increase over the previous 2 decades, likely related to the obesity epidemic as well as an aging population.
EFFECT OF SLEEP-DISORDERED BREATHING ON CARDIOVASCULAR HEALTH

- 15% of US population affected by a sleep breathing disorder
- Men AHI > 5/hr = 24% >15/hr = 9%
- Women AHI > 5/hr = 9% >15/hr= 4% (significant increase postmenopausal)
- OSA in HTN = 30%
- OSA in CHF = 38% in men and 31% in women

PATHOPHYSIOLOGY OF OBSTRUCTIVE APNEA
**PATHOPHYSIOLOGY OF OSA**

**Awake: Small airway + neuromuscular compensation**

- Loss of neuromuscular compensation
- Decreased pharyngeal muscle activity

**Sleep Onset**

- Hyperventilate: correct hypoxia & hypercapnia

**Airway opens**

- Pharyngeal muscle activity restored

**Apnea**

- Hypoxia & Hypercapnia

**Increased ventilatory effort**

- Arousal from sleep

- Airway collapses

**CONSEQUENCES: CARDIOVASCULAR**

- Obstructive Sleep Apnea
- Hypoxemia
- Reoxygenation
- Hypercapnia
- Intrathoracic Pressure Changes
- Arousal

**Intermediary Mechanisms**

- Sympathetic Activation
- Vasoconstriction
- Increased Catecholamines
- Tachycardia
- Impaired Cardiovascular Variability

- Endothelial Dysfunction
- Vascular Oxidative Stress
- Inflammation
- Increased Coagulation
- Metabolic Dysregulation
- Leptin Resistance
- Obesity
- Insulin Resistance

**Risk of Cardiovascular Disease**

- Hypertension
- Congestive Heart Failure
- Systolic Dysfunction
- Diastolic Dysfunction

- Cardiac Arrhythmia
- Bradycardia
- A-V Block
- Atrial Fibrillation

- Cardiac Ischemia
- Coronary Artery Disease
- Myocardial Infarction
- Nocturnal ST-Segment Depression
- Nocturnal Angina

- Cerebrovascular Disease

• Sleep apnea is characterized by repetitive episodes of apnea occurring during sleep.

• An apnea is defined as a cessation of inspiratory airflow lasting 10 seconds or more.

• Hypopnea refers to a reduction in inspiratory airflow (by at least 30%) lasting 10 seconds or more with an associated drop in oxygen saturation equal or ≥ 3% or arousal from sleep.

• The mechanism for apneas or hypopneas can be either obstructive, or central, in which both airflow and inspiratory efforts are absent. The term sleep-disordered breathing (SDB) encompasses OSA, central (CSA), and mixed apneas.

<table>
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<th>Obstructive</th>
<th>Mixed</th>
<th>Central</th>
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<td><img src="waveform_mixed.png" alt="Mixed Waveform" /></td>
<td><img src="waveform_central.png" alt="Central Waveform" /></td>
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</tbody>
</table>

• Severity is also determined using the AHI, with 5 to 14 considered mild, 15 to 29 moderate, and ≥ 30 severe disease.

• Treatment is recommended for everyone with AHI > 15. Or > 5 with signs/symptoms of sleep apnea or associated medical conditions (including hypersomnia, hypertension, HF, coronary artery disease, arrhythmias, and other forms of CVD).
**OSA & MORTALITY**

![Graph showing survival probability vs. years with different AHI (apnea-hypopnea index) categories](image)


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**Non-fatal Cardiovascular Events**

![Graph showing cumulative incidence of non-fatal CV events (%)](image)

CARDIOVASCULAR CONDITIONS ASSOCIATED WITH OSA

- Resistant Hypertension
- Heart Failure
- Atrial Fibrillation
- Other Arrhythmias
- Coronary Artery Disease, Cerebrovascular Disease, or Patients Without Established CVD Who Are at High Risk for Future Adverse Cardiovascular Events
- Perioperative Risk
- Pulmonary Hypertension

RESISTANT HYPERTENSION

- OSA, the relationship with hypertension is the best established. Multiple observational studies have demonstrated this association
- Resistant hypertension, commonly defined as inability to adequately control blood pressure despite use of 3 antihypertensive agents including a diuretic or adequate blood pressure control requiring ≥4 agents. For example, 1 study found the prevalence of OSA to be 71% in patients with resistant hypertension versus 36% in those with essential hypertension.

  A recent meta-analysis of 5 randomized trials enrolling 457 total patients found a significant reduction in 24-hour ambulatory blood pressure (4.78 mm Hg [95% CI, 1.61–7.95] systolic and 2.95 mm Hg [95% CI, 0.53–5.37] diastolic).
MHIF Cardiovascular Grand Rounds | November 22, 2021

**Hypertension and OSA by AHI**

*OR adjusted for age, sex, ethnicity, BMI, neck & waist circumference, smoking and alcohol use


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**OSA AND HYPERTENSION**

**TABLE 2. ADJUSTED ODDS RATIOS* OF INCIDENT HYPERTENSION AT FOLLOW-UP IN RELATION TO BASELINE APNEA-HYPOPNEA INDEX AMONG 2,470 SLEEP HEART HEALTH STUDY SUBJECTS WITHOUT HYPERTENSION AT BASELINE**

<table>
<thead>
<tr>
<th>Baseline AHI</th>
<th>n</th>
<th>Model 1</th>
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<th>Model 3</th>
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<td>0-4.9</td>
<td>1,511</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>5-14.9</td>
<td>629</td>
<td>1.13 (0.90-1.43)</td>
<td>0.92 (0.72-1.17)</td>
<td>0.94 (0.73-1.22)</td>
</tr>
<tr>
<td>&gt;15</td>
<td>34</td>
<td>1.34 (1.04-1.74)</td>
<td>1.22 (0.86-1.72)</td>
<td>1.09 (0.77-1.54)</td>
</tr>
</tbody>
</table>

*OR adjusted for age, sex, race, and time since baseline.

Definition of abbreviations: AHI = apnea-hypopnea index; BMI = body mass index.

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HEART FAILURE

Sleep apnea is highly prevalent in patients with HF

HSAT devices have not been validated to diagnose CSA, current guidelines recommend polysomnography

Sleep apnea is prevalent in patients with asymptomatic left ventricular dysfunction as well as those with clinically overt HF,

Coexisting sleep apnea has been associated with increased risk of adverse outcomes, including mortality, in patients with HF; increased risk of arrhythmias, sudden cardiac death, and an elevated risk of coronary events.

BENEFITS OF PAP THERAPY IN HF

• Reductions in sympathetic nervous system signaling have been observed in patients with both OSA and CSA treated with CPAP.

• PAP also reduces the pro-arrhythmic state associated with OSA, having been shown to decrease ventricular ectopy as well as the risk of recurrent AF.

• Furthermore, CPAP results in favorable hemodynamic effects, including improved left ventricular systolic and diastolic function in OSA patients with high wedge pressures.

• Post hoc analysis suggested a reduction in mortality among patients for whom CPAP therapy resulted in a significant improvement in AHI (to <15 events/h).
SLEEP HEART HEALTH STUDY: CROSS-SECTIONAL ANALYSIS

Adjusted Relative Odds of Prevalent Coronary Heart Disease, Heart Failure, or Stroke, by Quartile of SDB

Shahar E et al. Am J Respir Crit Care Med 2001

10,701 consecutive adults undergoing their first diagnostic polysomnogram between July 1987 and July 2003.

SCD was best predicted by:
- age >60 years (HR: 5.53)
- apnea-hypopnea index >20 (HR: 1.60)
- mean nocturnal O₂sat <93% (HR: 2.93)
- lowest nocturnal O₂sat <78% (HR: 2.60; all p < 0.0001).
Survival decreases as severity of obstructive sleep apnea increases.
ATRIAL FIBRILATION

- Similar to OSA, AF is common in the general population, with a prevalence of 1% to 2%.
- In patients with OSA, the prevalence of AF is \( \approx 5\% \), while notably the prevalence of OSA in patients diagnosed with AF has been reported as high as 32% to 39%.
- Independent association between the 2 disorders exists even after controlling for confounding conditions such as systemic hypertension, obesity, and HF.
- Alterations in both sympathetic and parasympathetic system regulation have been observed in association with OSA.

- But incomplete protection against apnea-associated AF induction suggests that additional mechanisms beyond neurohormonal activation are relevant.
- Over time, OSA promotes structural remodeling of both the ventricles and atria, providing an additional pro-arrhythmic mechanism. Exaggerated swings in intrathoracic pressure, as are seen during apneic events, have been shown to cause acute atrial dilation as well as increased frequency of premature beats.
- Significant slowing of atrial conduction also occurs during hypercapnia, even in the absence of hypoxia. The susceptibility to AF among patients with OSA likely reflects the combined effects of these various mechanisms.
**ATRIAL FIBRILLATION**

- Electrophysiologic studies of dilated left atria following repetitive apneic events have revealed slowed atrial conduction, reduced electrogram amplitudes, and complex fractionated atrial electrograms providing mechanistic support for atrial remodeling in AF related to OSA.

- Suggest referral and diagnostic testing in patients with suspected sleep apnea following comprehensive sleep assessment based on nocturnal symptoms and/or risk factors when catheter ablation is planned.

- This recommendation is consistent with the 2017 Heart Rhythm Society.

- **Meta-analysis**: 4572 patients with AF after successful catheter ablation were enrolled. Compared to patients without OSA, the pooled OR of recurrent AF in patients with OSA was 1.70 (95% CI).

- Among OSA patients with AF after successful catheter ablation, the use of CPAP was significantly associated with decreased risk of recurrent AF with pooled OR of 0.28.

*Effect of obstructive sleep apnea and its treatment of atrial fibrillation recurrence after radiofrequency catheter ablation: A meta-analysis*  
Among the pathophysiologic mechanisms linking OSA with CAD and cerebrovascular disease include:

- Increased sympathetic nervous system activity,
- Oxidative stress,
- Predilection to poorly controlled and/or resistant hypertension.
- Endothelial dysfunction
- Promotion of a procoagulable state
- Metabolic dysregulation characterized by insulin resistance
Treatment of OSA with CPAP has been shown to mitigate these processes.

Meta-analysis data revealed that in the 4 RCTs achieving median adherence >4 hours/night, PAP therapy was associated with a significantly lower risk of adverse cardiovascular events (relative risk 0.58; 95% CI, 0.34–0.99).
PULMONARY HYPERTENSION

- OSA is strongly associated with pulmonary hypertension (PH) and may play a causative role in its pathophysiology. Whereas ≈10% to 20% of patients with moderate-to-severe OSA have coexisting PH.

- The prevalence of OSA in patients with PH diagnosed by right heart catheterization has been estimated to be 70% to 80%.

- Pulmonary hypertension resulting solely from OSA is generally mild;

- Recommended overnight oximetry testing in patients with PH

- Patients with suspected sleep apnea should be referred for sleep consultation followed by formal polysomnography.

![Diagram](image-url)
OTHER ARRHYTHMIAS

• 22% prevalence of prolonged pauses and bradycardia in patients with moderate-to-severe OSA who received long-term monitoring with an implanted loop recorder.

• Significantly higher prevalence of nonsustained ventricular tachycardia (5.3% versus 1.2%, \( P=0.004 \)) among patients with severe OSA compared with controls.

• Similarly, severe OSA was associated with a significantly higher overall risk of complex ventricular ectopy.

CONSEQUENCES: ARRHYTHMIAS
DIAGNOSING SLEEP APNEA

OBSTRUCTIVE SLEEP APNEA RISK FACTORS

• Obesity
  • Increasing age
  • Male gender
  • Craniofacial anatomic abnormalities

• Alcohol or sedative use
• Smoking
• CV disease
• Family history
• Conditions decreasing upper airway tone
CENTRAL SLEEP APNEA

- Less common than obstructive sleep apnea
- Central respiratory control abnormality
- Heterogeneous conditions
  - Congestive Heart Failure
  - Normal individuals at high altitude
  - Primary Central Sleep Apnea
  - Structural brain or chest wall disease
  - Chronic narcotic use

DIAGNOSIS: HISTORY

- Snoring (most often loud, habitual)
- Apneas, nocturnal gasping or choking
  - Ask bed partner (witnessed apneas, but can be unreliable)
- Assess risk factors & common co-morbidities
- Daytime symptoms:
  - sleepiness, poor concentration
- Sleep symptoms:
  - insomnia, sleep disruption
  - Night sweats, nocturia

**DIAGNOSIS: OSA EXAM**

- **Vitals**: Blood Pressure, O2 saturation
- **Obesity**: BMI >35
- **Neck circumference**
  - >17” men, >16” women
- **Oral pharynx**: upper airway crowding
  - Lateral wall narrowing
  - Large tongue, high based
  - Large uvula and tonsils
  - High arched palate
  - Modified Mallampati

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**UPPER AIRWAY EXAM**

- **Class 1**: Full visibility of tonsils, uvula and soft palate
- **Class 2**: Visibility of hard and soft palate, upper portion of tonsils and uvula
- **Class 3**: Soft and hard palate and base of the uvula are visible
- **Class 4**: Only hard palate visible
DIAGNOSTIC CONCLUSIONS

• Signs and symptoms
  • Excessive daytime sleepiness
  • Hypertension and other cardiovascular sequelae

• Sleep study results
  • Apnea / hypopnea frequency
  • Sleep fragmentation (PSG)
  • Oxyhemoglobin desaturation

TREATMENT OBJECTIVES

• Reduce morbidity and mortality
  • Reduce sleepiness
  • Decrease cardiovascular, metabolic and other systemic consequences

• Improve quality of life
**THERAPEUTIC APPROACH**

- Risk counseling
  - Motor vehicle crashes
  - Job-related hazards (Pilots, Truck drivers, heavy machinery)
  - Judgment impairment
- Apnea and co-morbidity treatment
  - Behavioral
  - Medical
  - Surgical

**BEHAVIORAL INTERVENTIONS**

- Encourage patients to:
  - Lose weight (if overweight)
  - Avoid alcohol and sedative-hypnotics
  - Avoid sleep deprivation
  - Avoid supine sleep position in susceptible patients
  - Stop smoking
  - Maintain clear nasal passages
WEIGHT LOSS

• Should be strongly encouraged for all obese patients
• Can be curative but has low success rate
• Other treatment is required
  • Until optimal weight loss is achieved
  • And sleep apnea is proven to be resolved

MEDICAL INTERVENTIONS

• Positive airway pressure
  • Continuous positive airway pressure (CPAP)
  • Fixed CPAP
  • Auto-positive airway pressure or APAP
  • Bi-level positive airway pressure
    • Fixed bi-level positive airway pressure (BPAP)
    • Variable positive airway pressure (VPAP)

• Oral appliances

• Hypoglossal nerve stimulation

• Other (limited role): medications, oxygen
POSITIVE AIRWAY PRESSURE
**BENEFITS OF CPAP: SLEEPINESS & FUNCTIONAL OUTCOMES**


- FOSQ = Functional Outcomes of Sleep Questionnaire
- ESS = Epworth Sleepiness Scale
- MSLT = Multiple Sleep Latency Test

**POSITIVE AIRWAY PRESSURE: PROBLEMS**

- Mask Discomfort
- Patient Acceptance
- Claustrophobia
- Aerophagia
- Chest Discomfort
CPAP COMPLIANCE: PREDICTORS

- Predict Good Compliance
  - Increased AHI
  - Increased daytime sleepiness
  - Perception of benefit

- Predict Poor Compliance
  - Lack of EDS
  - Lack of perceived benefit
  - Nasal obstruction
  - Side effects
  - Claustrophobia
  - PTSD

STRATEGIES TO IMPROVE COMPLIANCE

- Patient Education
- Frequent and early follow-up
- Desensitization
- Machine-patient interfaces
  - Masks
  - Nasal pillows
  - Chin straps
- Humidifiers
- Ramp
CPAP MASKS

BI-LEVEL POSITIVE AIRWAY PRESSURE
Positive Pressure Therapy

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<th>Pressure</th>
<th>CPAP</th>
<th>Bi-level</th>
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<td>![Pressure Graph]</td>
<td>![Bi-level Pressure Graph]</td>
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<th>Flow</th>
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<tbody>
<tr>
<td>![Flow Graph]</td>
<td>![Bi-level Flow Graph]</td>
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MONITORING ADHERENCE TO PAP THERAPY

ORAL APPLIANCE
GENERAL PRINCIPLE
ORAL APPLIANCES
TREATMENT PREREQUISITES

- OSA status must be clarified
  - Oral appliances indicated for primary snorers and mild-moderate OSA
- Qualified dental expertise crucial
  - Assess candidacy for oral appliance
  - Adequate healthy teeth
  - No important TMJ disorder
  - Adequate jaw range of motion
  - Adequate manual dexterity and motivation to position device
  - Fit and monitor oral appliance

ORAL APPLIANCES
TREATMENT CONSIDERATIONS

- Adherence: varies between studies
  - 77% at 1 year
- Side effects: frequency varies between studies
  - Pain: TMJ; myofascial; tooth; gum
  - Dry-mouth, salivation, morning occlusal changes
- Combined dental and sleep follow-up important
  - Sleep study after optimal fit to look for residual OSA
  - Periodic dental visits to assess device, oral health
MEDICAL THERAPY: SUPPLEMENTAL OXYGEN

- Not a primary treatment for obstructive sleep apnea - not standard of care and not routinely recommended
- Does not improve daytime sleepiness
- May prolong apneas
- Reduces oxygen desaturation during apneas
- Reduces arrhythmias

SURGICAL TREATMENT OF OSA

- OSA status must be clarified pre-operatively
- Multidisciplinary patient assessment important
  - Identify anatomic surgical targets
  - Assess for significant co-morbidities
  - Determine patient’s desire for surgery
  - Counsel on options, benefits, risks, and alternatives
- Potential candidates
  - Primary therapy: mild OSA + severe, but surgically remediable, obstructing anatomy
  - Secondary therapy: unsuccessful response to PAP and/or OA
  - Adjunctive therapy: increase tolerance of PAP or OA
- Post-operative sleep specialist follow-up recommended
UVULOPALATOPHARYNGOPLASTY (UPPP)

Maxillofacial Surgeries

- Genioglossal advancement
- Maxillomandibular advancement
META-ANALYSIS OF MAXILLOMANDIBULAR ADVANCEMENT (MMA)

<table>
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<th>Study or Subgroup</th>
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<td>Dekelester, 2006</td>
<td>0.10 [0.10, 0.24]</td>
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<td>Kessler, 2007</td>
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<td>Prinsen, 1999</td>
<td>0.08 [0.05, 0.12]</td>
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<td>Riley, 1980</td>
<td>0.12 [0.09, 0.16]</td>
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<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>0.13 [0.08, 0.20]</strong></td>
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Heterogeneity: Tau² = 0.42; Chi² = 92.92; df = 8; P < 0.00001; I² = 91%
Test for overall effect: Z = 8.70 (P = 0.00001)

Pooled reduction in AHI with MMA: 87%

Coples SM, et al. Sleep 2010;33

HYPOGLOSSAL NERVE STIMULATOR

- Neurostimulator delivers electrical pulses to the hypoglossal nerve (stimulation lead)
- The pulses are synchronized with ventilation (sensing lead)
- 3 incisions are required

Stimulation OFF

Stimulation ON
Upper airway pacing

Consists of three components: an implantable generator, a breathing sensor lead, and a stimulation lead.

Controlled by a handheld sleep remote.

Turn the therapy on at night before bed, and off in the morning when you wake up.

TONGUE REPOSITIONING DEVICE
POSITIONAL THERAPIES

OBSTRUCTIVE SLEEP APNEA

VS
QUESTIONS?

REFERENCES

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