Sleep-Disordered Breathing

Similarities and Differences between Pediatrics and Adults

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No disclosures
Objectives:
At the end of this session, the participant would be able to:

• Discuss the similar complications of sleep disordered breathing including obesity, cardiovascular and neurologic dysfunction and explain how these manifestations may differ in adults compared to children

• Identify prevention strategies to avoid these complications and discuss the different approaches between pediatric and adult management of sleep disordered breathing
Wish we all could have a good night sleep!

• Rechtschaffen (1971) “if sleep does not serve an absolute vital function, then it is the biggest mistake the evolutionary process ever made…”

• Neuroplasticity
  - sleep linked to memory and learning
  - pediatric sleep disorders in the first 5 years of life associated with special educational need at 8 years of age

_Pediatrics_ 2012;130:634–642
Recommended hours of sleep in children

• Ages 4-12 months: 12-16 hours (including naps)
• Ages 1-2 years: 11-14 hours (including naps)
• Ages 3-5 years: 10-13 hours (including naps)
• Age 6-12 years: 9-12 hours
• Age 13-18 years: 8-10 hours

• a consensus statement of the American Academy of Sleep Medicine
• endorsed by the American Academy of Pediatrics
• Sleep is essential for optimal health

Adverse consequences

- Pulmonary hypertension
- Cor pulmonale
- Endothelial dysfunction
- Insulin resistance
- Dyspilidemia
- Increased healthcare usage
- Nocturnal enuresis

- Neurocognitive impairment
- Hyperactivity
- Attention deficits
- Concentration difficulties
- Impulsivity
- Excessive daytime sleepiness
## OSA estimated prevalence

### Pediatrics
- **parent-reported questionnaire:** 4 to 11%
- **diagnostic studies:** 1 to 4%
- **snoring by any definition (meta-analysis):** 7.45%

### Adults
- **diagnostic studies:**
  - (AHI ≥15 events per hour; or AHI ≥5 with at least one clinical symptom)
  - 15% (males)
  - 5% (females)

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## OSA – epidemiology

### Pediatrics
- race: African American
- age: peak prevalence between 2 and 8 years
- gender: boys > girls
- Second cohort:
  - Obese adolescents

### Adults
- race: African Americans who are younger than 35 years old
- age: increases from young adulthood through 6\textsuperscript{th} to 7\textsuperscript{th} decade
- gender: males (2 to 3 times) > females
- gap narrows at age of menopause

Prevalence of OSA in the US increasing due to rising rates of obesity.
## OSA – risk factors

### Pediatrics
- Adenotonsillar hypertrophy
- Obesity
- Recurrent otitis media and sinusitis, asthma
- Smoke exposure and maternal smoking during pregnancy
- Prematurity; delayed motor milestones
- Prenatal and perinatal stressors

### Adults
- Obesity
- Craniofacial and upper airway abnormalities
- Nasal congestion
- Smoking
- Menopausal and postmenopausal
- Substances and medications
  - Alcohol, narcotics, benzodiazepines

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JAMA. 2004;291(16):2013

## OSA – medical conditions

### Pediatrics
- Cerebral palsy
- Down syndrome
- Craniofacial anomalies
- Orthodontic problems
- History of low birth weight
- Neuromuscular disorders
- Metabolic / storage diseases
- Achondroplasia
- Prader-Willi syndrome

### Adults
- Pregnancy
- Congestive heart failure
- End-stage renal disease
- Chronic lung disease
- Stroke and transient ischemic attacks
- Acromegaly
- Hypothyroidism
- Polycystic ovary syndrome
- Craniofacial and upper airway abnormalities

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## OSA symptoms

### Pediatrics

- **Nighttime symptoms**
  - Snoring/witnessed apnea, mouthbreathing, choking, gasping, sweating, restless sleep, agitated sleep, unusual positions-hyperextended neck
  - Parasomnias may be associated with OSA
  - Sleep terrors, sleep walking, or confusional arousals
  - Nocturnal enuresis

### Adults

- **Nighttime symptoms**
  - Snoring, restlessness, or resuscitative snorts
  - The bed partner reports loud snoring, or interruptions in breathing while sleeping

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## OSA symptoms

### Pediatrics

**Daytime symptoms**
- mouth breathing and hyponasal speech
- headache in the morning
- EDS may be less obvious than in adults
  - age-inappropriate daytime napping, sleepiness, or falling asleep in school, on short car rides, or on the school bus

### Adults

**Daytime symptoms**
- Excessive daytime sleepiness (EDS)
- Fatigue
- Poor concentration

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## OSA Physical Findings

### Pediatrics

<table>
<thead>
<tr>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>• may be obese or grow poorly</td>
</tr>
<tr>
<td>• tonsil size</td>
</tr>
<tr>
<td>• Craniofacial anomalies</td>
</tr>
<tr>
<td>• Adenoid facies</td>
</tr>
<tr>
<td>• Decreased nasal airflow, hyponasal speech</td>
</tr>
<tr>
<td>• Mucosal or turbinate swelling</td>
</tr>
<tr>
<td>• Allergic manifestations - dark circles under the eyes, swollen eyes, transverse nasal crease</td>
</tr>
</tbody>
</table>

### Adults

<table>
<thead>
<tr>
<th>Common Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Obesity</td>
</tr>
<tr>
<td>• Crowded oropharyngeal airway</td>
</tr>
<tr>
<td>• large neck circumference</td>
</tr>
<tr>
<td>• hypertension</td>
</tr>
</tbody>
</table>

• Micrognathia/retrognathia

significant overbite suggests a small jaw, which may be due to abnormal maxillomandibular development
• High-arched and narrow hard palate
• Overlapping incisors
Tonsils and adenoids

• Most common cause of upper airway obstruction is lymphoid hypertrophy (of tonsils and adenoids)
Evaluation of adenoids

Laryngoscopy

Lateral Neck Film
FIGURE 1 - Patient with severe OSAS. Craniofacial and cervical morphology demonstrating a Class II standard with mandibular bony base involvement, short neck, widened cervical circumference and excess fat in the submental region.
### OSA polysomnographic features

<table>
<thead>
<tr>
<th>Pediatrics</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Obstructive apneas, hypopneas, respiratory effort related arousals (RERAs) – airflow limitation</td>
<td>• Obstructive apneas (more discrete), hypopneas, or RERAs</td>
</tr>
<tr>
<td>• obstructive hypoventilation common in young children</td>
<td></td>
</tr>
<tr>
<td>• continuous partial collapse the airway</td>
<td></td>
</tr>
<tr>
<td>→ increased upper airway resistance → hypoventilation (hypercapnia)</td>
<td></td>
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</tbody>
</table>

The spectrum of sleep disordered breathing in children

- **Normal**
- **Primary Snoring** (PS)
- **Upper Airway Resistance Syndrome** (UARS)
- **Obstructive Hypoventilation** (OH)
- **Obstructive Sleep Apnea Syndrome** (OSAS)

Graph showing the spectrum of sleep disordered breathing in children:

- O2 desaturations
- ETCO2
- Respiratory arousals
- Airflow alteration
- Snoring
Severity of OSA based on PSG guidelines

<table>
<thead>
<tr>
<th>Severity</th>
<th>AHI (per hour)</th>
<th>O₂ saturation nadir</th>
<th>ECO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0-1</td>
<td>&gt;92%</td>
<td></td>
</tr>
<tr>
<td>Mild OSA</td>
<td>2-4</td>
<td></td>
<td>ECO₂ &gt;50 mmHg for 10-24% TST</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-9</td>
<td></td>
<td>ECO₂ &gt;50 mmHg for 25-49% TST</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;10</td>
<td>&lt;80%</td>
<td>ECO₂ ≥50 mmHg for &gt;50% TST</td>
</tr>
</tbody>
</table>

Guide for remembering severity of OSA in children in comparison to adults

- **Children AHI index**

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<th>Moderate</th>
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<td>0-1</td>
<td>2-4</td>
<td>5-9</td>
<td>&gt;10</td>
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- **ECO2 in children (>50 mm Hg in TST)**

<table>
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<th>Normal</th>
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<tr>
<td>&lt;10%</td>
<td>10-24%</td>
<td>25-49%</td>
<td>&gt;50%</td>
</tr>
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</table>

- **Adults AHI index**

<table>
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<th>Normal</th>
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<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>5-15</td>
<td>15-30</td>
<td>&gt;30</td>
</tr>
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</table>
OSAS – complications

**Pediatrics**
- Cardiovascular
- Growth
- Neurobehavioral abnormalities
- Inflammation
- Quality of life (family unit)

**Adults**
- Cardiovascular risk factors
- Metabolic syndrome
- Cognitive deficits
- Surgical risk
- Quality of life

Sleep. 2013;36(9):1297
OSA and cardiovascular disease - ADULTS

• hypertension
• coronary heart disease
• cardiac arrhythmia
• heart failure
Sleep disordered breathing (SDB) in Atrial Fibrillation (AF)

• Sleep disordered breathing is recognized as a notable factor in atrial fibrillation

• Moderate to severe SDB has been shown to adversely affect LV diastolic function in candidates for AF ablation.

*Heart And Vessels*, 2016. 3(7), 1140.
Pathophysiology

- repetitive episodes of apnea or reduced inspiratory airflow
- significant increase in sympathetic activity
- heart rate and blood pressure

**different mechanisms:**
- chemoreflex stimulation by hypoxia and hypercapnia
- baroreflexes
- pulmonary afferents

- impairment in venous return to the heart
- alterations in cardiac output and the arousal response
- endothelial dysfunction
Autonomic dysfunction in OSA

• Why is OSA linked to hypertension?
  • elevated levels of plasma and urinary catecholamines
  • lack of the normal pattern of reduction of blood pressure during sleep (ie, a non-dipping blood pressure)

Circulation. 1999 Dec;100(23):2332-5
Clinical evidence

- increased prevalence of hypertension in OSA
  - even after controlling for confounding factors (age and obesity)

- Consistent findings in cross-sectional population-based studies
Memory and OSA - Adults

- Memory impairment
- Lack of concentration
- Even depression and anxiety

Neurobehavioral morbidity in children

• Probable mechanistic role?
• MRI data showed greater activity in regions of the brain implicated in cognitive control, conflict monitoring and attentional allocation for children with OSA (in order to perform same tasks at same level)

Cardiovascular dysfunction

- blood pressure
- echocardiographic findings
  - left ventricular dysfunction
  - increased pulmonary pressures
  - end-diastolic dysfunction
- autonomic functions
- inflammatory markers
  - C-reactive protein
  - N-terminal pro–B-type natriuretic peptide
Cardiovascular morbidities in children

oxidative stress alters the endothelial cells and leads to endothelial "dysfunction"

Genetic  environment

Resolution after adenotonsillectomy but persist in subgroup with strong family history of cardiovascular disease
Severity is greater in children who are obese and have OSA
Blood pressure in pediatric OSA

- blood pressure and heart rate changes during obstructive events (similar in magnitude in adults) (O’Driscoll, 2009)

- a strong, dose-dependent relationship between elevated BP and severity of SDB (Li, 2004; Amin 2004, 2008)

Children with severe OSA have significantly greater mean BP during wakefulness and sleep
• Hypertension

Effect of AHI on BP at median BMI percentile of 75.21

- Diastolic day
- Systolic night
- Diastolic night

BP vs AHI graph
Intermittent hypoxemia

• in critical stages of development, augment effects of systemic inflammation and metabolic alterations

→ diabetes and vascular disease risks in later life

• Epidemic of obesity: 1 of 3 children may be at risk for developing diabetes
Neurocognitive Dysfunction - Pediatrics

• even children with primary snoring
  • performance deficits compared with controls (attention, overall cognitive functioning, language, and visuospatial abilities) (O’Brien 2003, 2004)

• impairments in neuropsychological functioning may be result of sleep or gas exchange abnormalities (Khadra, 2008; Gozal 2010)
• Reasonable:
children with learning or attention problems or poor academic functioning
→ should be evaluated for SDB in the clinical setting
• Poor academic performance
  • first graders lowest 10\textsuperscript{th} percentile with 18\% of significant SDB symptoms (Gozal D. Pediatrics 1998;102:616–620.)

• High scores on hyperactivity scales
Attention Deficit Disorder and Sleep disordered breathing (ADHD and SDB)

• overlap between ADHD and SDB
  • 25% of children with ADHD also had SDB symptoms (i.e., snoring) (Chervin, Sleep 2001;24:313–320)
  • 28% of children scheduled for T and A meet the DSM-IV-R criteria for ADHD (Dillon, J Am Acad Child Adolesc Psychiatry 2007;46:1425–1436.)
  • 50% of those children no longer met ADHD criteria one year post-operatively
# First line treatment

## Adenotonsillectomy
- Adenotonsillectomy is first line therapy for otherwise healthy children who have OSA and adenotonsillar hypertrophy
- Alternatives
  - Watchful waiting
  - CPAP
  - Intranasal steroids
  - Weight loss

## CPAP
- Positive airway pressure therapy is the mainstay of therapy for adults with OSA
- Alternatives
  - Oral appliance
  - Upper airway surgery
  - Pharmacologic
  - Weight loss
RME versus oral appliance

**Pediatrics**
- RME (rapid maxillary expansion) or Palate expander
  - From age 8 years up to pubertal period

**Adults**
- mandibular advancement splints
- tongue retaining devices
Rapid maxillary expansion

• What is RME?
  • orthodontic appliance deliver a lateral force to the upper posterior molars, opens the midpalatal suture transversely and therefore widens the nasal cavity

Sleep 2004;27:761–6.
Bimaxillary Expansion Therapy

- A form of RME
- Procedure involves screw-activated expansion devices that is installed onto the dentition
- Shows promise as a treatment option for refining respiratory parameters in pediatric sleep-dis ordered breathing

Sleep Medicine, 2016. 3045-51.
Oral appliance

advancement splint from dental impressions with adjustability of mandibular position by means of a screw
Proposed classification of pediatric OSA

- two types of OSA in children (Gozal, et al)
  - Type I – adenotonsillar hypertrophy
  - Type II – obese children and adolescents
  - analogy with type I and type II diabetes

- (Type III - variety of craniofacial and neuromuscular disorders)
  - Crouzon and Apert syndromes, Pierre Robin sequence, Down syndrome, Goldenhar syndrome, achondroplasia, myelomeningocele, and cerebral palsy
  - Careful meta-analysis first needed!!!

Special populations
High rate of sleep problems in “special” populations

- basic sleep—wake patterns should form part of routine history-taking
  - especially if child's daytime behavior or mood are suggestive of sleep deprivation
- extended assessment to diagnose and treat the underlying sleep disorder
- treatment decisions need to be based not only on the type of sleep disorder but also, within reason, on the family's preferences and abilities.

Down’s syndrome

- Poor sleep
  - reduced REM sleep and increased slow-wave sleep independent of OSA
  - implications for learning, memory, and behavior
- Anatomy: maxillary hypoplasia and small nose with low nasal bridge midface
- Recurrent upper airway infections → adenotonsillar hypertrophy
- Hypotonia

Craniofacial anomalies

• clinical findings - snoring, work of breathing, desaturations
• congenital craniofacial anomalies is strongly associated with inpatient diagnosis of OSA
• anatomic features - maxillary or mandibular hypoplasia, crowded oropharynx, macroglossia, or poor motor tone

Craniosynostosis

- significant maxillary hypoplasia
- estimated prevalence of OSA of 53% in this population based on symptom report

Apert syndrome
Crouzon syndrome
Pfeiffer syndrome
Oromaxillofacial procedures

• surgical advancement of the midface to enlarge the upper airway

Le Fort II or Le Fort III procedure (internal or external distraction devices)

• substantially reduced the AHI and improved oxygen saturation in a cohort of 11 children (Pfeiffer, J Plast Reconstr Aesthet Surg. 2013 Sep;66(9):1206-1211.)
Pierre Robin Sequence
Treatment strategies depend on the severity of compromised airways

- palatal plate with a pharyngeal extension
- Palatal obturator with dorsal extension
- Nasopharyngeal intubation
- Glossopexy
- Mandibular distraction osteogenesis
- Tracheotomy
- Timely and sequential palatal reconstruction

Suction and drinking plate with pharyngeal extension
Pierre Robin sequence surgery

- Tongue-lip adhesion and tongue repositioning can improve apnea/hypopnea index (AHI) and oxygenation saturations

- Systematic review (90 patients)

  - Tongue-lip adhesion
    - AHI from 30 to 18 events per hour (50% reduction)
    - Lowest oxygen saturation from 75% to 84%

  - Tongue repositioning
    - AHI from 46 to 17 events per hour (62% reduction)
    - Mean oxygen saturation from 90 to 95%

Autism spectrum disorder (ASD)

• Sleep problems as high as 80% in children with ASD
• Sleep problems and insufficient sleep →
  - daytime sleepiness, learning problems and behavioral issues
  - hyperactivity, inattentiveness and aggression
• most common sleep problems
  - difficulty falling asleep and repeated awakenings
  - very prolonged awakenings or awaken very early for the day
• sleep of other family members is often impacted
Poor sleep in ASD

• Neurological
  - abnormalities in brain systems that regulate sleep
  - melatonin and other chemicals released by the brain

• Medical
  - epilepsy or gastroesophageal reflux can disrupt sleep
  - medications taken can be alerting and contribute to difficulty falling asleep

• Psychiatric
  - anxiety and/or depression can interfere with sleep

• Behavioral
Medical Burden and Age

- Medical burden and severity of sleep disorders increase significantly with age
- Sleep wake symptoms decreased with age (daytime drowsiness, insomnia, fatigue)
- Advancing age may be associated with a decrease in symptom awareness

*Journal Of The American Geriatrics Society, 2015. 63(9), 1845-1851.*
Summary

• Adults
  • Adverse outcomes include excessive daytime sleepiness, inattention, fatigue, and cardiovascular morbidities such as resistant systemic hypertension
  • severe untreated OSA (ie, AHI >30 events per hour) at increased risk for all-cause mortality
Summary

• Pediatrics

• Inattention, learning problems, and behavioral problems (eg, hyperactivity, impulsivity, rebelliousness, and aggression) associated with OSA in children.

• Excessive daytime sleepiness is also associated with OSA, but may not be present, especially in young children.
Similarities - Pediatrics and Adults

- blood pressure and heart rate changes during obstructive events (similar in magnitude in pediatrics and adults)
- adolescents with SDB
  - 6.5-fold higher risk of metabolic syndrome
- emergence of a phenotypic variant of OSA in children and adolescents
  - closely resembles that of adults with the disease
- significant effects on attention, cognitive functioning, memory and general intellectual abilities