Pediatric Obstructive Sleep Apnea and Hypoventilation Syndromes

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Outline

- Definitions and Epidemiology
- Pathophysiology
- History and Physical
- Polysomnography
  - Pediatric Scoring Rules
  - Limits of utility of Polysomnogram in diagnosis of Pediatric Obstructive Sleep Apnea
- Treatment.
Spectrum of Disease

Primary Snoring

- Primary Snoring
  - Snoring but no polysomnographic abnormalities
  - Some studies suggest that some of these patients have significant consequences.
  - Habitual snoring in 3-12% of the population and 1-3% have OSA

Katz et. al. 2005
Definitions

- Upper Airway Resistance Syndrome
  - Brief repetitive, respiratory related arousals during sleep in the absence of overt apnea, hypopnea, or gas exchange abnormalities
  - It has been linked to significant cognitive and behavioral sequelae in children including learning disabilities, attention deficit, hyperactivity, and aggressive behavior.

Katz et. al. 2005
Definitions

- **Obstructive Sleep Apnea Syndrome**
  - Recurrent episodes of partial or complete airway obstruction resulting in hypoxemia, hypercapnia, and/or respiratory arousal.
  - Children with OSA can develop a combination of oxidative stress, inflammation, autonomic activation, and disruption of sleep homeostasis.
  - OSA may produce metabolic, cardiovascular, and neurocognitive side effects.

  *Katz et. al. 2005*
Epidemiology

- Not been precisely established
  - Diagnostic criteria make populations studies difficult
  - Few population based studies
- Habitual Snoring is always observed in OSA
  - Reliability of a negative clinical history of snoring is poor in older children.
Epidemiology

- Sample size greater than 1000 with representative questionnaire based studies and whether objective testing was performed
  - 27% snored sometimes.
  - 11.7% snored ≥ 3 times a week
  - 10.9% almost always snored
  - 4.2% always snored
  - 2.2 to 3.8% OSA determined objectively
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size Adenoids, Tonsils</td>
<td>Increased airway resistance.</td>
</tr>
<tr>
<td>Obesity</td>
<td>Fatty infiltration airway, abnormal ventilatory control</td>
</tr>
<tr>
<td>Race (African American)</td>
<td>Craniofacial Structure, Socioeconomic</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td>Slight male preponderance in pre puberty but increases dramatically after</td>
</tr>
<tr>
<td>Prematurity</td>
<td>Neuro impairment. Abnormal Craniofacial growth, Abnormal Ventilatory control</td>
</tr>
<tr>
<td>Craniofacial Abnorm</td>
<td>Increased airway resistance</td>
</tr>
<tr>
<td>Neurologic D/O</td>
<td>Abnormal motor control of upper airway</td>
</tr>
<tr>
<td>Nasal Pharyngeal Inflam.</td>
<td>Allergy or infection increases airway resistance</td>
</tr>
<tr>
<td>Socio/Economic/Environ</td>
<td>Passive Cigarette Smoke, Indoor Allergens, neighborhood disadvantage</td>
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<tr>
<td>FH of OSA</td>
<td>Heritable craniofacial Structure, Neuromuscular compensation, ventilatory control, Arousal Threshold</td>
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<td></td>
<td>Adult OSA</td>
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<tr>
<td>----------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Sleepiness</td>
<td>Frequent</td>
</tr>
<tr>
<td>Hyperactivity</td>
<td>Less Common</td>
</tr>
<tr>
<td>Cause</td>
<td>Obesity, Narrow Pharynx</td>
</tr>
<tr>
<td>Gender</td>
<td>M &gt; F</td>
</tr>
<tr>
<td>Age</td>
<td>Middle Age</td>
</tr>
<tr>
<td>PSG</td>
<td>Sleep Disruption</td>
</tr>
<tr>
<td>Oxygen Desat</td>
<td>Greater</td>
</tr>
<tr>
<td>Respiration</td>
<td>Apnea/Hypopnea</td>
</tr>
<tr>
<td>RERA</td>
<td>More frequent</td>
</tr>
<tr>
<td>Primary Rx</td>
<td>PAP</td>
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Pathophysiology of OSA

- Anatomy
- Airway Mechanics
- Neuromuscular Compensation, Arousal Ventilatory Control
- Obesity
Pathophysiology of Pediatric OSA

Airway Narrowing

Obstructive Sleep Apnea

Abnormal Neuromuscular Control

Obesity

Genetics
Anatomy

- Children with OSA have narrower pharyngeal airways and increased nasal resistance to controls.
  - The correlation between apnea severity and adenotonsillar size is variable.

- Areas of obstruction
  - Adenotonsillary hypertrophy
  - Maxillary constriction
  - Retrognathia and Micrognathia.
Cross-Section of Oropharynx

- Nasal obstruction
- Tonsillar hypertrophy
- Micro- or retrognathia
- Large tongue
Anatomy

- Mouth breathing children
  - Lower their mandible
    - Results in high arched palate
    - Narrow maxilla
    - Retrognathia
    - Increased lower facial height.
  - Predisposing patients to development of OSA
  - In long run, changes in craniofacial development can increase risk future development OSAS
  - Treatment may at least partially normalize dentofacial abnormalities.
Adenoidal Facies or “Long face syndrome”
Airway Mechanics

- Airway is a highly compliant tube in which small changes in pressure produces large changes in cross-sectional area.

- Upper airway muscles keep the airway open during wake periods decrease in activity during sleep.
  - The decreased muscle is even more decreased in REM.
Airway Mechanics

- The critical closing pressure is the luminal pressure at which airway collapse occurs.
- The critical closing pressure (Pcrit) is higher in children with OSA
  - In patients with OSA after T & A, the Pcrit in these patients is still higher than controls suggesting subtle anatomic and neuromuscular control abnormalities.
Neuromuscular Compensation, Arousal, and Ventilatory Control

- Upper airway muscles, such as the genioglossus, increased both the luminal size and the stiffness of the airway.
Neuromuscular Compensation, Arousal, and Ventilatory Control

- Children with OSAS have increased genioglossus activity compared to controls.
- At sleep onset, pharyngeal dilator activity is reduced, ventilatory variability increases, apneic threshold increases in non REM sleep.
- Airway collapse is offset by increased pharyngeal dilatory activity in non REM sleep.
Neuromuscular Compensation, Arousal, and Ventilatory Control

- Arousals from sleep immediately opens the airway and normalizes gas exchange abnormalities.
  - Potentiates obstructive cycling by augmenting ventilatory overshoot
  - Interferes with sleep homeostasis.
- REM sleep further reduces pharyngeal dilator activity which is cause of disproportionate severity of OSA in REM.
Obesity

- Prevalence of childhood obesity has tripled over the past 25 years and is estimated at 17 to 18%
- Incidence of OSA in children is high as 36% and may exceed 60% if habitual snoring is present.
- Risk of having moderate OSAS increases by 12% for each 1 kg/m² of BMI above mean
Obesity

- However the relationship between BMI and OSAS severity is often poor.
  - Fat distribution is of considerable importance.
- Obesity contributes to OSA influences
  - Dimension and collapsibility of the upper airway
  - Ventilatory control
- Obesity and OSA are both chronic low grade inflammatory states
  - Synergistically produce significant cardiovascular, metabolic and neurocognitive morbidities.
Pathophysiology of Pediatric OSA

Airway Narrowing

Obesity

Abnormal Neuromuscular Control

Genetics

Obstructive Sleep Apnea
Sequelae of Obstructive Sleep Apnea

- Obstructive Sleep Apnea is a systemic, inflammatory, oxidative stress, atherosclerogenic, metabolic, and societal disorder. Teofolo Lee Chiong MD

- Described Pediatric Sequelae
  - Metabolic
  - Cardiovascular
  - Neurocognitive
Metabolic Sequelae of Pediatric OSA

- Elevated CRP
- Insulin Resistance
- Hypercholesterolemia
- Elevated Transaminases
- Decreased insulin like growth factor
- Decreased or altered growth hormone secretion
Neurocognitive Sequelae of Pediatric OSA

- Decreased Quality of Life
- Aggressive Behavior
- Poor school performance
- Depression
- Attention Deficit
- Hyperactivity
- Moodiness
Cardiovascular Sequelae of Pediatric OSA

- Autonomic Dysfunction
- Systemic Hypertension
- Absent Blood Pressure Dipping
- Left Ventricular Dysfunction
- Pulmonary Hypertension
- Abnormal Heart Rate Variability
- Elevated Vascular Endothelial Growth Factor.
History – Nocturnal Symptoms

- Sleep history
  - Snoring: unlikely to have sleep apnea if no history of snoring
    - Older patients may be the exception and history may not be accurate.
  - Respiratory pauses while sleeping
  - Increased work of breathing
  - Paradoxical respirations
  - Enuresis
  - Restless sleep
History - Nocturnal Symptoms

- Sleep history
  - Choking while sleeping
  - Restless sleep
  - Hyper extended neck
  - Frequent awakenings
  - Mouth breathing or dry mouth
  - Increase in parasomnias such as sleep walking
History – Diurnal Symptoms

- **Sleep Excessive daytime sleepiness**: 7.5% of patients with history of OSA syndrome have this complaint
  - Napping
  - Morning headaches
  - Difficulty arousing during sleep

- **Upper Airway**
  - Mouth breathing
  - Nasal congestion
  - Frequent otitis media or sinusitis
  - Nasal speech
History – Diurnal Symptoms

- Neurocognitive.
  - Poor school performance
  - Aggressive behavior
  - Attention deficit disorder
  - Hyperactivity
  - Depression
  - Moodiness
History – Associated Conditions

- History during wakefulness
  - Neurologic disorders such as Cerebral Palsy
  - Genetic Syndromes such as Down’s Syndrome
  - Structural Abnormalities of the head and neck such as cleft palate, Pierre-Robin Sequence.
Syndromes & Conditions Associated with OSA in Children

Downs Syndrome

Apert’s/Crouzon’s Syndrome
Syndromes & Conditions Associated with OSA in Children

Treacher Collins Syndrome

Achondroplasia
Syndromes & Conditions Associated with OSA in Children

Prader Willi

Hunter’s Syndrome
Syndromes & Conditions Associated with OSA in Children

Pierre Robin Sequence

Cleft Lip and Palate

Credit: Wikipedia
Syndromes & Conditions Associated with OSA in Children

Spina Bifida

Muscular Dystrophy, Spinal Muscular Atrophy, Cerebral Palsy
Syndromes & Conditions Associated with OSA in Children

Morbid Obesity

Sickle Cell Disease
Physical Exam

- **General**
  - Sleepiness
  - Obesity
  - Failure to Thrive
  - Neck Size > 17” associated with OSA in Adults

- **Cardiovascular**
  - Hypertension
  - Loud P2

- **Extremities**
  - Clubbing
  - Edema

- **Neurologic**
  - Increased tone
  - Developmental Delay
Cross-Section of Oropharynx

- Nasal obstruction
- Tonsillar hypertrophy
- Micro- or retrognathia
- Large tongue
Physical Exam: HEENT

- Swollen nasal mucosa
- Deviated Septum
- Adenoidal Facies
  - Infraorbital darkening
  - Elongated Face
  - Mouth Breathing
- Tonsillar Hypertrophy
- High Arched Palate
- Overbite
- Crowded Oropharynx
- Macroglossia
- Glossoptosis
- Midfacial Hypoplasia
- Micrognathia
- Retrognathia
Facial Findings: Midface Hypoplasia
Facial Findings:
Micrognathia/Retrognathia
Facial/Mouth Findings: Retrognathia and Macroglossia

Retrognathia  Macroglossia  Glossoptosis
Facial Findings: Adenoidal Facies, Long Face Syndrome

- Infraorbital darkening
- Mouth Breathing
- Elongated Midface
- Nasal Atrophy
Nasal Findings: Edematous Nasal Turbinates
Nasal Findings: Deviated Septum
Mouth Findings: Scoring Tonsils

0

1+

2+

3+

4+
Mouth Findings: Tonsillar Hypertropy
Mouth Findings: Mallampati Score

Class I  Class II  Class III  Class IV
Mouth Findings: High Arched Palate
Mouth Findings: Bifid Uvula with submucosal cleft.
Mouth Findings: Buccal Cross Bite
Mouth Findings: Overbite
Recognition of OSA in Children

- Difficult to predict diagnosis of sleep apnea based on awake evaluation
  - Parents may miss night time symptoms
  - Daytime symptoms in children can be subtle
  - Presence of snoring is helpful but only predictive that will have snoring on the sleep study.
- Physical Exam can be normal
- 50/50 chance correct diagnosis based on clinical assessment.
Diagnostic Studies

- The gold standard for the diagnosis of obstructive sleep apnea is polysomnography.
- Ancillary data such as xrays, Hct, serum bicarbonate, EKG, echocardiogram, and neurocognitive testing are non specific.
- Home video recordings can be helpful with sensitivity of 92% but specificity of 29% as it misses subtler forms of OSA.
Pediatric Polysomnography

EEG

EOG

Nasal EtCO2

Chin EMG (2)

Sao2

Respiratory Effort

Nasal Oral Airflow

Microphone

EKG

Leg EMG (2)

Tech Observer

Documents arousals, parasomnias, abnormal sleeping position, and attends to any technical problem

Video Camera

Record behavior

Courtesy of Dr. Carol Rosen
Pediatric Scoring Rules

- Obstructive Apnea Rules
  - Event lasts for 2 missed breaths as opposed to 10 seconds in adults.
  - > 90% fall in signal amplitude
  - Associated with continued respiratory effort during the event.
Pediatric Scoring Rules

- Central Apnea
  - Apnea event with at least 2 missed breaths
  - Absent inspiratory effort throughout the cycle
  - And 1 of the following
    - Event lasts 20 seconds or longer or
    - Lasts 2 missed breaths with and is associated with an arousal, an awakening, 3% desaturation.
Pediatric Scoring Rules

- Mixed Apnea
  - Event lasts for 2 missed breaths as opposed to 10 seconds in adults.
  - > 90% fall in signal amplitude
  - Absent inspiratory effort for the initial portion of the event followed by resumption of inspiratory effort before the end of the event.
Pediatric Scoring Rules

- Pediatric Hyponea Rules.
  - Greater than 50% fall in the amplitude of the nasal pressure compared to baseline excursion
  - The event lasts for at least 2 missed breaths.
  - Fall in nasal pressure signal amplitude must last for $\geq 90\%$ of the event.
  - $\geq 3\%$ desaturation or arousal or awakening
Pediatric Scoring Rules

- Hypoventilation Rule
  - When 25% of the total sleep time as measured by ETCO2 sensor (or transcutaneous) is spent greater than 50 mm Hg
  - In adults ≥ a 10 mm Hg increase from awake to sleep in supine position.
Pediatric Scoring Rules

- **Respiratory Effort Related Arousal**
  - Fall in Nasal Pressure signal but less than 50%
  - Flattening of the Nasal Pressure Waveform
  - Event associated with snoring, noisy breathing, elevation of ETCO2, visual increased work of breathing
  - Lasts 2 breath cycles
  - In adults sequence of breaths lasting 10 seconds characterized by the above leading to an arousal.
Polysomnogram: Normals

- **Respiratory Parameters**
  - Obstructive Apnea Index/h TST 0.0 ± 0.1
  - Apnea Hypopnea Index/h TST 0.1 ± 0.1
    - Includes Central, Obstructive, Hypopneic
  - Central Apnea Index/h TST 0.5 ± 0.5
  - %TST ET CO2 > than 50 2.8 ± 11.3
  - Peak ET CO2 46 ± 3
  - Oxygen Saturation < 90% (%TST) 0.05 ± 0.2
Classification of OSA

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Apnea Index (Events/hr)</th>
<th>(\text{Spo}_2) Nadir (%)</th>
<th>(P_{\text{ET , CO}_2}) Peak (torr)</th>
<th>(P_{\text{ET , CO}_2} &gt; 50) torr (% TST)</th>
<th>Arousals (Events/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary snoring</td>
<td>(\leq 1)</td>
<td>&gt;92</td>
<td>(\leq 53)</td>
<td>&lt;10</td>
<td>EEG &lt; 11</td>
</tr>
<tr>
<td>Upper airway resistance syndrome</td>
<td>(\leq 1r)</td>
<td>&gt;92</td>
<td>(\leq 53)</td>
<td>&lt;10</td>
<td>RERA &gt; 1</td>
</tr>
<tr>
<td>Mild OSAS</td>
<td>1-4</td>
<td>86-91</td>
<td>&gt;53</td>
<td>10-24</td>
<td>EEG &gt; 11</td>
</tr>
<tr>
<td>Moderate OSAS</td>
<td>5-10</td>
<td>76-85</td>
<td>&gt;60</td>
<td>25-49</td>
<td>EEG &gt; 11</td>
</tr>
<tr>
<td>Severe OSAS</td>
<td>&gt;10</td>
<td>(\leq 75)</td>
<td>&gt;65</td>
<td>(\geq 50)</td>
<td>EEG &gt; 11</td>
</tr>
</tbody>
</table>

*Each diagnosis requires one or more of the measures to its right.

EEG, electroencephalographic arousal; OSAS, obstructive sleep apnea syndrome; \(P_{\text{ET \, CO}_2}\), end tidal \(\text{Pco}_2\); RERA, respiratory-related arousal; \(\text{Spo}_2\), arterial oxygen saturation; TST, total sleep time.

Katz et. al. 2005

These criteria are based on the clinical experiences at a large sleep center, **but are not considered standard.**
Limits of Polysomnography

- Efforts were made to gauge severity using variables such as AHI
  - Mild 1-5/h, Moderate 5-10/h, Severe > 10/hr
  - Gas exchange
  - Sleep fragmentation.
- Problem is that threshold of OSA associated with adverse consequences varies widely among children.
- Efforts underway to use polysomnographic data with symptoms, biomarker, genomic profile to come up with plan.
Limits of Polysomnography

- Some children are not fulfilling statistical criteria for “disease” may be symptomatic and display measurable morbidity while other children who fulfill statistical criteria for disease may not exhibit end-organ morbidity.

- At any given level of OSA severity, there are children with neurocognitive deficits and otherwise age, gender, ethnicity, maternal education, BMI matched children who do not have neurocognitive deficits.
Limits of Polysomnography

- Primary Snoring is associated with increased risk for neurocognitive and behavioral disturbances, increased cardiovascular risk, enuresis, and insulin resistance risk.
Limits of Polysomnography

- Dilemmas
  - Treating every habitual snorer is excessive
  - The PSG alone will not guide us on how to treat these patients.
  - Not treating patients who are affected is wrong as well
  - However the treatment has measureable morbidity and mortality.
  - Unclear how to identify the vulnerable Primary Snorer.
Model of Pediatric OSA

**Environmental**
- Food
- Exercise
- Pollution
- Literacy

**Individual Susceptibility**
- ApoE
- TNF-alpha
- FABP4
- Polymorphisms
- Genetic Disorders

**Severity of Sleep Disordered Breathing**

- Age
- Obesity
- Prematurity

Gozal 2012
Limits of Polysomnogram

- PSG by itself is not adequate to assess for Pediatric OSA
- Need History and Physical to look for possible areas of end organ involvement.
- With patients with primary snoring or mild sleep apnea, need to have discussions around these issues and come up with a plan.
Treatment of Pediatric OSA

- Make decisions on etiology, severity, therapeutic options
- Adenotonsillectomy is first line treatment.
- CPAP would be appropriate for some patients depending on the etiology.
- For patients with severe OSA and severe sequelae tracheostomy is option.
Adenotonsillectomy

- Initial studies had that this procedure was curative of OSA, but subsequent studies have shown that a smaller percentage (in 1 study 27.2% improved to an AHI less than 1)

- Possible predictors of failure
  - Obesity
  - Severe OSA on initial PSG
  - Asthma is also associated, possibly related to the inflammation that it produces.
  - Craniofacial disorders, Genetic Syndromes, and Neurologic disorders more likely to have persistent findings
Adenotonsillectomy

- For this reason, many patients in these groups will need to have a PSG after T and A to see if there is resolution of their symptoms.
- Also these patients seem to have more perioperative complications as well.
Perioperative Management of Children with OSA

- Assess those patients with higher risk
  - Severe OSA on PSG
  - Age < 3 years old
  - Obesity
  - Mallampati score 3 to 4
  - Neuromuscular, Genetic, Craniofacial Disorders
  - Cor Pulmonale
  - Growth failure due to OSA
  - Hypertension
  - URI within 4 weeks of surgery.

Following surgery, high risk patients should be observed overnight in a facility where appropriate monitoring and care are available.
Preoperative Management

- For some patients with severe sleep apnea needing surgery, CPAP or BiPAP will be started prior to the procedure and titrated during a PSG.
- This can be used in the post operative phase.
- Another sleep study can be done post operatively to determine the need of continued CPAP or retitrate with the hope for lower settings.
Postoperative management

- Complications ranged from 6.4% to 27%.
- AHI greater than 10 and age less than 3 years old were the highest risk groups.
- Other factors associated with increase risk:
  - Genetic Syndromes
  - Craniofacial Abnormalities.
  - Neuromuscular disorders.
Postoperative management

- Complications ranged from 6.4% to 27%
- Nursing interventions in 60%
  - Increased work of breathing
  - Oxygen desaturations
  - Changes on CXR
    - Edema, atelectasis, infiltrate, pneumothorax, pneumomediastinum, pleural effusion
  - Laryngospasm
  - Apnea
  - Pulmonary Hypertensive crisis
  - Pneumonia
  - Perioperative Death
Postoperative management

- For some patients the tonsillectomy and adenoidectomy may not be curative.
- For many, obstructive sleep apnea can still be seen in the post operative period especially the night after.
- Also because of the possibility of obstructive sleep apnea remaining, some patients will need a Polysomnogram afterwards.
Children on CPAP
Positive Airway Pressure
CPAP for OSA

- Some patients do not have adenotonsillar hypertrophy or are not a candidate for surgery or did not respond to surgery.
- These patients are candidates for CPAP therapy.
- The difficulty is compliance and data suggests that even with the support of professionals compliance is 65 to 70%
Special Considerations for CPAP in Children

- Need wide variety of mask sizes and styles to fit children
- Compliance may be enhanced by behavioral techniques
  - Empowerment
  - Positive reinforcement
  - Desensitization
  - Role modeling
Oral Appliances

- Could be used but only when patients are fully matured teeth in face as in adults.
  - Most effective for mild OSA and supine sleep
  - Studied on only small scale in children
- Another option which is being studied is rapid maxillary expansion which may helpful in patients with high arched palates.
  - Limited study and needs further investigation
Pharmacological Treatments

- Intranasal steroids or Oral steroids
  - A variety of steroids have shown to decrease proliferation rate of lymphoid tissue.
  - Long term benefit unclear but short term studies did show benefit.
  - May be beneficial in patients with mild SDB, patients with seasonal symptoms, and for those where surgery is not indicated.
Pharmacological Treatments

- Leukotriene Receptor Antagonists (Singulair)
  - Tonsillar and adenoidal tissue shown to have an abundance of leukotrienes and their receptors
  - 1 small trial showed improvement in 54% of patients who had mild sleep disordered breathing after adenotonsillectomy

- With better understanding of the mechanisms of Sleep disordered breathing at the cellular level, novel treatments may emerge over time.
Conclusions

- Obstructive Sleep apnea in children causes significant Metabolic, Cardiovascular and Neurologic.
- A comprehensive evaluation in which a sleep study is included is needed to identify those who need treatment.
- Stratifying risk is important in preparation for surgical intervention to help minimize operative complications.
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