Consequences of Pediatric Obstructive Sleep Apnea (OSA)

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Conflict of Interest Disclosures

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Objectives

- Describe basic sleep study terminology related to OSA
- Describe neurodevelopmental outcomes associated with pediatric OSA
- Describe cardiopulmonary outcomes associated with pediatric OSA

Basic Sleep Study Terminology

Pediatric Definitions per American Academy of Sleep Medicine (AASM) Scoring Manual:

- Oxygen desaturation: SpO2 decrease of ≥3% from baseline
- Oxygen desaturation index (ODI): number of desaturations averaged out over the total sleep time, reported as average number of events per hour

Berry 2018

Pediatric Definitions per AASM Scoring Manual (cont'd):

- Apnea: ≥90% reduction in airflow for 2 breaths
- Hypopnea: ≥30% reduction in airflow for 2 breaths that is associated with an arousal or oxygen desaturation
- Obstructive Apnea: apnea associated with the presence of respiratory effort (trying to breathe, but can't get the air in)
- Obstructive Hypopnea: hypopnea associated with evidence of obstructed airflow (snoring, thoraco-abdominal paradox, or blunted inspiratory airflow)
- Apnea hypopnea index (AHI): number of apneas and hypopneas averaged out over the total sleep time, reported as average number of events per hour

Berry 2018

Outcomes

STEP 2: Recognition of morbidity and conditions coexisting with SDB:
2.1 Morbidity
Cardiovascular system
a) Elevated blood pressure
b) Pulmonary hypertension and cor pulmonale
Central nervous system
a) Excessive daytime sleepiness
b) Inattention/hyperactivity
c) Cognitive deficits/academic difficulties
d) Behavioural problems
Enuresis and somatic growth delay or growth failure
Decreased quality of life
2.2 Conditions coexisting with SDB (probably common pathogenesis)
a) History of recurrent otitis media or tympanostomy tube placement
b) Recurrent wheezing or asthma
c) Metabolic syndrome
d) Oral-motor dysfunction

Kaditis 2016

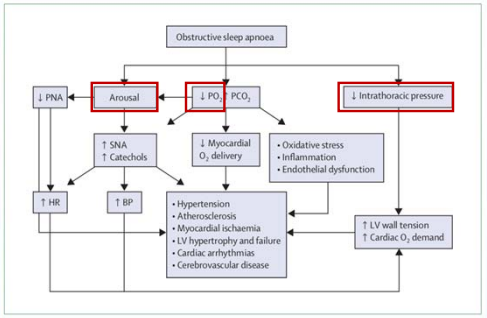


Figure: **Pathophysiological effects of obstructive sleep apnoea on the cardiovascular system**
PNA=parasympathetic nervous system activity. PO_2=partial pressure of oxygen. PCO_2=partial pressure of carbon dioxide. SNA=sympathetic nervous system activity. HR=heart rate. BP=blood pressure. LV=left ventricular.

Bradley 2009

Neurodevelopmental Outcomes

TABLE 2—Adverse Effects of Pediatric OSAS on the Central Nervous System and the Results of Treatment Interventions

Pathophysiologic and clinical abnormalities	Evidence for reversibility after OSAS treatment? (reference no.)
Higher subjective scores of excessive daytime sleepiness (e.g., modified Epworth sleepiness scale score, pediatric sleep questionnaire-sleepiness subscale)	Yes[7]
Objective measures of excessive daytime sleepiness (e.g., increased mean sleep latency in the multiple sleep latency test)	Yes[60]
Attention-deficit hyperactivity disorder symptomatology	Yes[2,60]
Cognitive deficits and academic difficulties	Yes[60,66–68,70]
Behavioral problems	No (pre-school children)[70] Yes[60,77]

Tan 2017

The Childhood Adenotonsillectomy Trial (CHAT)

- Inclusion criteria:
  - 5-9 years old
  - OSA confirmed by in-lab PSG at study center (OSA defined as oAHI ≥2, or oAI ≥1)
  - Tonsil size ≥ 1+
  - Deemed suitable candidate for AT by ENT surgeon
- Exclusion criteria:
  - AHI >30 or oAI >20
  - Hypoxemia (SpO2 <90% for ≥2% of TST)
  - Craniofacial or airway abnormalities that would interfere with standard practice T&A
  - Recurrent tonsillitis
  - Clinically significant cardiac arrhythmia
  - BMI z-score >2.99
  - Severe medical problems that could be exacerbated by delayed treatment of OSA
  - Known chronic medical conditions likely to affect the airway, cognition, or behavior
  - Current use of: ADHD medications, psychotropic medication, hypoglycemic agents or insulin, antihypertensives, growth hormone, anticonvulsants, anticoagulants, daily oral corticosteroids.
  - Psychiatric or behavioral disorders likely to require initiation of new medication or treatment during the 7-month study period

Redline 2011

CHAT (cont'd)

- Subjects randomized to early AT (within 4wks of randomization) or watchful waiting
- Polysomnographic, cognitive, behavioral, sleep dysfunction, quality of life, and cardiometabolic parameters evaluated at baseline and at 7 months

Redline 2011

Table 1. Baseline Characteristics of Patients Who Completed the Study.*

Characteristic	Watchful Waiting (N=203)	Early Adenotonsillectomy (N=194)
Age — yr	6.5±1.4	6.5±1.4
Male sex — no. (%)‖	106 (52)	89 (46)
Race — no. (%)†		
Black	108 (53)	103 (53)
White	76 (37)	67 (35)
Other	19 (9)	24 (12)
Hispanic ethnicity — no. (%)†	17 (8)	15 (8)
Height — cm	124.7±10.5	125.1±11.2
Height z score	0.6±1.0	0.7±1.0
Weight — kg	30.1±11.7	31.2±13.1
Weight z score	1.0±1.2	1.0±1.3
Weight class — no. (%)‡		
Overweight or obese	94 (46)	93 (48)
Obese	67 (33)	68 (35)
Failure to thrive	3 (1)	4 (2)
Maternal educational level less than high school — no. (%)	64 (32)	62 (32)
Annual household income <$30,000 — no. (%)	82 (40)	73 (38)

Marcus 2013

Table 2. Outcome Measures.*

Outcome	Normative Mean	Watchful Waiting		Early Adenotonsillectomy		Effect Size†	P Value
		Baseline	Change from Baseline to 7 Mo	Baseline	Change from Baseline to 7 Mo		
Primary outcome							
NEPSY attention and executive-function score‡	100±15	101.1±14.6	5.1±13.4	101.5±15.9	7.1±13.9	0.15	0.16
Secondary outcomes							
Conners' Rating Scale score§	50±10						
Caregiver rating		52.6±11.7	−0.2±9.4	52.5±11.6	−2.9±9.9	0.28	0.01
Teacher rating		55.1±12.8	−1.5±10.7	56.4±14.4	−4.9±12.9	0.29	0.04
BRIEF score¶	50±10						
Caregiver rating		50.1±11.5	0.4±8.8	50.1±11.2	−3.3±8.5	0.28	<0.001
Teacher rating		56.4±11.7	−1.0±11.2	57.2±14.1	−3.1±12.6	0.18	0.22
PSQ-SRBD score‖	0.2±0.1	0.5±0.2	−0.0±0.2	0.5±0.2	−0.3±0.2	1.50	<0.001
PedsQL score**	78±16	76.5±15.7	0.9±13.3	77.3±15.3	5.9±13.6	0.37	<0.001
Apnea–hypopnea index — no. of events/hr††	NA						
Median		4.5	−1.6	4.8	−3.5	0.57	<0.001‡‡
Interquartile range		2.5 to 8.9	−3.7 to 0.5	2.7 to 8.8	−7.1 to −1.8		

- Effect sizes calculated by Cohen's d; relates the magnitude of group difference to the standard deviation:
  >0.20 - 0.49 small effect size; 0.50 - 0.79 medium effect size; ≥0.80 large effect size

Marcus 2013

Cardiovascular Outcomes

TABLE 1— Adverse Effects of Pediatric OSAS on the Cardiovascular System and the Results of Treatment Interventions

Pathophysiologic and clinical abnormalities	Evidence for reversibility after OSAS treatment? (reference no.)
Increased nocturnal heart rate	Yes[36–38,43]
Decreased heart rate variability	Yes[38]
Increased blood pressure variability and decreased baroreflex sensitivity	Yes[28,29]
Elevated awake systolic and diastolic blood pressure (average of triplicate measurements)	No change in blood pressure percentile post-adenotonsillectomy[43]
Increased left ventricle afterload	–
Decreased left ventricle ejection fraction	–
Decreased left ventricle diastolic function (mitral valve inflow velocity)	Yes[39]
Increased mean pulmonary artery pressure	Yes[40]
Decreased right ventricle ejection fraction	Yes[30,31]
Increased cardiac strain (increased blood brain natriuretic peptide levels)	Yes[37,41]
Endothelial dysfunction	Yes[14,42]

Tan 2017

Pulmonary Artery Pressures

Pulmonary artery pressures before and after T&A

Table 1
The comparison of the mPAP values of the children with TAH in preoperative period and controls

(N = 85)	Mean	SD	Statistics
Pulmonary arterial pressure			
Patient group (n = 52)	23.13	7.68	Nonpaired *t* test
Control group (n = 33)	16.11	7.24	(Levene's test) ($P < .05$)

Table 2
The comparison of the mPAP values of the children with TAH in preoperative and postoperative period

(N = 52)	Mean	SD	Statistics
Pulmonary arterial pressure			
Preoperative	23.13	7.68	Paired sample *t* test
Postoperative	17.00	6.99	($P < .05$)

Yilmaz 2005

Pulmonary artery pressures before and after T&A

Table 2 mPAP levels preoperatively and postoperatively

mPAP	Study, mean ± S.D.	Control, mean ± S.D.	*p*
Prop	26.26 ± 5.40	16.54 ± 2.63	0.001**
Postop	16.61 ± 2.68	16.54 ± 2.63	0.922

**statistically significant.

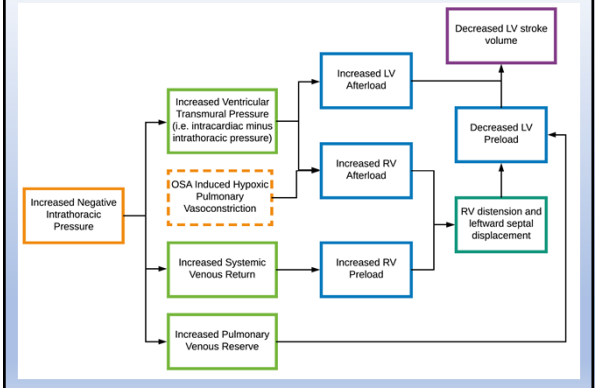
Table 3 Distribution of the number of hypertensive and normotensive patients preoperatively and postoperatively

mPAP	Study, *n* (%)	Control, *n* (%)	*p*
Preop			
Hypertensive	33 (84.6%)	2 (10.5%)	0.001**
Normotensive	6 (15.4%)	17 (89.5%)	
Postop			
Hypertensive	2 (5.1%)	2 (10.5%)	0.591
Normotensive	37 (94.9%)	17 (89.5%)	

**statistically significant.

Naiboglu 2008

Impaired Cardiac Function



Figured created from text provided by Kasai 2012

TABLE 1 Demographic and Polysomnographic Characteristics of the Study Population

	Primary Snoring	Obstructive Sleep Apnea		
	Group 1 (n = 15)	Group 2 (n = 23) Apnea Hypopnea Index	Group 3 (n = 25)	
Variable	<1	1–5	>5	p Value
Demographic variables				
Age (yrs)	10.5 ± 3.5	10.2 ± 3.7	12.1 ± 3.9	NS
No. of males	8 (53%)	17 (73%)	16 (64%)	NS
No. of Caucasians	87%	61%	64%	NS
Body mass index (kg/m²)	23.7 ± 8	25.3 ± 9.3	31 ± 11†	0.02
Systolic blood pressure (mm Hg)	112 ± 13	115 ± 11	117 ± 15	NS
Diastolic blood pressure (mm Hg)	64 ± 9	70 ± 6	65 ± 9	NS
Polysomnographic variables				
Apnea hypopnea index (25–75% quartiles)	0.1 (0.1–0.1)	2.8 (2.1–3.5)*	24 (10–33)†‡	<0.0001
Desaturation index (no./ h)	0.6 (0.1–1.2)	1.5 (0.4–2.6)	11 (5–19)†	<0.0001
Lowest saturation	92 (90–93)	90 (86–92)	83 (78–86)†‡	<0.0001
Maximum CO_2 (mm Hg)	49 (48–51)	52 (49–54)	54 (50–57)†	<0.0001
Arousal index (no./h)	12.3 (7–14)	9.4 (7–11)	17 (11–25)†‡	<0.0001

Demographic characteristics are expressed as mean ± SD.
Polysomnographic characteristics are expressed as median and interquartile range (25%–75%).
*p <0.05 group 1 versus group 2; †p <0.05 group 1 versus group 3; ‡p <0.05 group 2 versus group 3.

Amin 2005

Diastole

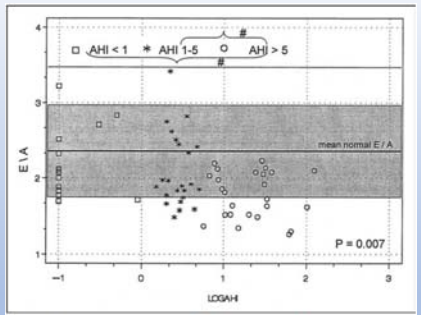


FIGURE 1. Decreases in mitral inflow velocity with increasing AHI. The overall difference among the 3 groups is reflected in the p value. #p <0.05 for group 1 versus 3 and group 2 versus 3. *Shaded background*, mean ± 1 SD of published normal values for the E/A ratio.[5]

Amin 2005

Systole

TABLE 2 Systolic Function and Contractile State of the Left Ventricle

Groups	Normal Values	Primary Snoring: Apnea Hypopnea Index <1	Obstructive Sleep Apnea: Apnea Hypopnea Index 1–5	Obstructive Sleep Apnea: Apnea Hypopnea Index >5
Ejection fraction (%)	55 ± 5	62 ± 5	59 ± 6	60 ± 6
Shortening fraction (%)	32 ± 6	40 ± 5	42 ± 5	40 ± 4
Rate-corrected velocity of circumferential fiber shortening (circ/s)	1.03 ± 0.18	1.23 ± 0.23	1.24 ± 0.21	1.24 ± 0.18
Delta rate-corrected velocity of circumferential fiber shortening (circ/s)	0.003 ± 0.03	0.54 ± 0.22†	0.6 ± 0.23	0.48 ± 0.18

Normal values for different variables are shown.
Results are expressed as mean ± SD.
p = NS.

Amin 2005

Obstructive AHI: ≤2 >2, ≤5 >5

Table 1
Summary statistics and significance of comparisons between study groups regarding subjects characteristics and polysomnography indices. Continuous variables are expressed as mean ± standard deviation.

Variables	Primary snoring (n = 19)	Mild SDB (n = 13)	Moderate-to-severe SDB (n = 14)
Age (years)	7.5 ± 2.6	6.1 ± 2.5	5.1 ± 2.1
Obese (%)	6 (31.6)	4 (30.8)	6 (42.9)
Body mass index z-score	0.9 ± 1.3	0.6 ± 1.3	1.2 ± 1.9
Systolic blood pressure index (%)	−12.2 ± 8.9	−10.4 ± 8	−6.4 ± 11.3
Diastolic blood pressure index (%)	−16.4 ± 8.8	−12.9 ± 12.5	−10.9 ± 14.8
OAHI index* (episodes/h)	1.2 ± 0.6	3.1 ± 0.7	16.6 ± 11.6
Respiratory arousal index* (episodes/h)	0.7 ± 0.4	1.7 ± 0.5	4.4 ± 3.7
Oxygen desaturation of hemoglobin (> 4%) index* (episodes/h)	1.1 ± 0.8	2.6 ± 1	18.8 ± 13.7
SpO_2 nadir* (%)	91.3 ± 2.1	89.8 ± 2.7	78.6 ± 8.1

Abbreviations: **OAHI,** obstructive apnea-hypopnea index; **SDB,** sleep-disordered breathing; **SpO_2,** oxygen saturation of hemoglobin by pulse oximetry.
* $p < 0.01$ for comparisons of moderate-to-severe SDB group vs. mild SDB or vs. primary snoring groups.

Table 2
Summary statistics and significance of comparisons between study groups regarding indices of systolic cardiac function. Continuous variables are expressed as mean ± standard deviation.

Indices of systolic function	Primary snoring (n = 19)	Mild SDB (n = 13)	Moderate-to-severe SDB (n = 14)
RV ejection fraction area (%)	42.3 ± 11.4	38.2 ± 11	39.3 ± 9.6
LV shortening fraction* (%)	37.7 ± 4.4	36.9 ± 3.2	34.3 ± 5.5
LV ejection fraction* (%)	72.3 ± 5.9	71.7 ± 6.4	66.9 ± 7.9
Mitral annular (lateral) Sm (cm/s)	9.4 ± 1.8	9.3 ± 2	8.9 ± 1.7
Mitral annular (at IV septum) Sm (cm/s)	8 ± 1 (in 13 subjects)	7.7 ± 1.4 (in 6 subjects)	8.4 ± 1.5 (in 9 subjects)
Tricuspid annular (lateral) Sm (cm/s)	12.7 ± 1.7	12.5 ± 2.6	13.4 ± 2 (in 13 subjects)

Abbreviations: **IV septum**, interventricular septum; **LV**, left ventricle; **RV**, right ventricle; **SDB**, sleep-disordered breathing; **Sm**, systolic tissue Doppler velocity.
* $p < 0.05$ for comparison of moderate-to-severe SDB group vs. primary snoring group.

Kaditis 2010

Obstructive AHI: ≤2 >2, ≤5 >5

Table 4
Summary statistics and significance of comparisons between study groups regarding indices of diastolic function. Continuous variables are expressed as mean ± standard deviation.

Indices of diastolic function	Primary snoring (n = 19)	Mild SDB (n = 13)	Moderate-to-severe SDB (n = 14)
Doppler indices			
LV E/A	1.8 ± 0.5	1.7 ± 0.4	1.7 ± 0.4
MV E wave deceleration time (ms)	157.1 ± 24.4	148.8 ± 20.8	153.9 ± 27.9
LV isovolumic relaxation time (ms)	58.3 ± 14.2 (in 17 subjects)	59.7 ± 6.3 (in 12 subjects)	55.1 ± 11.2 (in 13 subjects)
RV E/A	1.5 ± 0.5 (in 15 subjects)	1.6 ± 0.4 (in 9 subjects)	1.3 ± 0.3 (in 12 subjects)
TDI indices			
Em/Am of mitral annulus-lateral corner	2.8 ± 0.8(in 18 subjects)	3.1 ± 0.9	2.79 ± 1
Em/Am of tricuspid annulus-lateral corner	1.6 ± 0.4	1.73 ± 0.5	1.8 ± 0.7 (in 13 subjects)
E/Em (mitral annulus-lateral corner)	5.8 ± 1.1(in 18 subjects)	5.7 ± 1.2	6.1 ± 1.2
E/Em (tricuspid annulus-lateral corner)	4.7 ± 1.9	4.4 ± 1.8	4.2 ± 1.4 (in 13 subjects)

Abbreviations: E/A, ratio of early (E) to late (A) wave peak inflow velocities (mitral or tricuspid valve); E/Em, ratio of peak early (E) wave inflow velocity by Doppler to early (Em) diastolic myocardial velocity by tissue Doppler imaging (mitral or tricuspid valve); Em/Am, ratio of peak early (Em) to late (Am) diastolic myocardial velocity by tissue Doppler imaging; LV, left ventricle; MV, mitral valve; RV, right ventricle; SDB, sleep-disordered breathing; TDI, tissue Doppler imaging.
p = non-significant for all comparisons.

Table 5
Summary statistics and significance of comparisons between study groups regarding indices of cardiac structure. Continuous variables are expressed as mean ± standard deviation.

Indices of cardiac structure	Primary snoring (n = 19)	Mild SDB (n = 13)	Moderate-to-severe SDB (n = 14)
LA maximal area (cm^2)	9 ± 3.4	8.6 ± 2.8	9.2 ± 1.3
LV end-diastolic diameter (cm)	3.8 ± 0.4	3.6 ± 0.5	3.5 ± 0.4
LV posterior wall thickness (cm)	0.6 ± 0.1	0.6 ± 0.2	0.6 ± 0.1
IV septum thickness (cm)	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1
Relative LV wall thickness	0.3 ± 0.04	0.3 ± 0.04	0.3 ± 0.04
LV mass index (g/height $^{2.7}$)	30.3 ± 7.7	32.4 ± 11	31.5 ± 6.8
RV area in diastole (cm^2)	10.9 ± 3.3	9.5 ± 3	10.2 ± 1.8
RV area in systole (cm^2)	6.2 ± 2	5.9 ± 1.9	6.3 ± 1.8
RV free wall thickness (cm)	0.4 ± 0.1 (in 16 subjects)	0.3 ± 0.08 (in 11 subjects)	0.4 ± 0.1 (in 12 subjects)

Abbreviations: **IV septum**, interventricular septum; **LA**, left atrium; **LV**, left ventricle; **RV**, right ventricle; **SDB**, sleep-disordered breathing.
p = non-significant for all comparisons.

Kaditis 2010

STEP 2: Recognition of morbidity and conditions coexisting with SDB:
2.1 Morbidity
Cardiovascular system
- a) Elevated blood pressure
- b) Pulmonary hypertension and cor pulmonale

Central nervous system
- a) Excessive daytime sleepiness
- b) Inattention/hyperactivity
- c) Cognitive deficits/academic difficulties
- d) Behavioural problems

Enuresis and somatic growth delay or growth failure
Decreased quality of life

2.2 Conditions coexisting with SDB (probably common pathogenesis)
- a) History of recurrent otitis media or tympanostomy tube placement
- b) Recurrent wheezing or asthma
- c) Metabolic syndrome
- d) Oral-motor dysfunction

European Respiratory Society Task Force on the diagnosis and management of obstructive sleep disordered breathing (SDB) in childhood.

Kaditis AG, et al. Obstructive sleep disordered breathing in 2- to 18-year-old children: diagnosis and management. Eur Respir J. 2016 Jan;47(1):69-94.

Kaditis 2016

Questions that Remain

- Statistical support for the clinical consequences of OSA remains equivocal in a number of areas
- Improvement of clinical outcomes with treatment of underlying OSA
  - Most recent studies focus on trying to answer this question (e.g. CHAT); suggest moderate improvement in a number of areas
- Risk stratification for clinical outcomes based on AHI level – just starting to get into this
- Risk stratification for clinical outcomes based on chronic duration of OSA
  - If OSA is only present for a few years during childhood should we be concerned? Studies like CHAT suggest YES
  - Stay tuned for follow-up studies on CHAT participants 5, 10, and 20 years down the road
- Risk stratification for clinical outcome based on severity/duration of underlying OSA insults (i.e. intermittent hypoxemia, negative intrathoracic pressure, arousals)

What to do Now?

When and Why to Treat the Child who Snores?

PSG: AHI > 5/h even if no morbidity present	○ Decreased likelihood to resolve spontaneously ○ AHI will be normalized in 1 of 3 children post-AT ○ Heart rate decreases in parallel with AHI reduction
AHI 1-5/h and sleepiness, inattention, behavioral problems, learning difficulties, growth failure, enuresis or history of obesity	○ Improvement in executive functioning, behavior, EDS and QOL are related to pre-treatment symptom severity and not pre-treatment AHI; somatic growth rate acceleration; enuresis resolution ○ OSAS less likely to resolve in the presence of obesity
AHI >1/h and genetic syndromes, craniofacial abnormalities or neuromuscular disorders	○ Increased risk of pulmonary hypertension if OSAS left untreated ○ OSAS might further compromise cognitive function in children with Down syndrome
Primary snoring	○ Limited evidence for improvement of hyperactivity symptoms, mouth-breathing, nasal congestion, difficulty swallowing

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The Children's Sleep Center Team

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- Diane Workman, Sleep Clinic Nurse

The Children's Sleep Center Team

- Heather Bohan, Respiratory Therapy

- Danielle Brazzle, Respiratory Therapy

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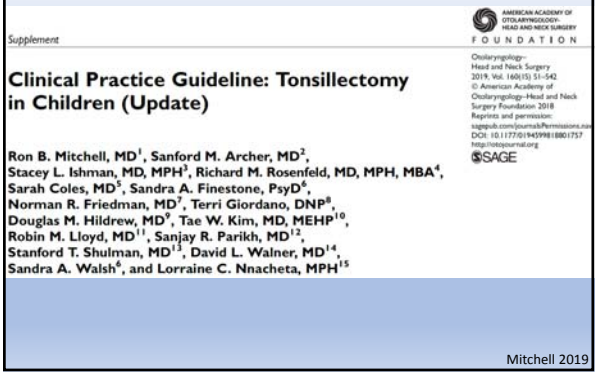
Supplementary Slides

Updated Recommendations from American Academy of Otolaryngology-Head and Neck Surgery

Current Guidelines



Supplement

Clinical Practice Guideline: Tonsillectomy in Children (Update)

Ron B. Mitchell, MD[1], Sanford M. Archer, MD[2], Stacey L. Ishman, MD, MPH[3], Richard M. Rosenfeld, MD, MPH, MBA[4], Sarah Coles, MD[5], Sandra A. Finestone, PsyD[6], Norman R. Friedman, MD[7], Terri Giordano, DNP[8], Douglas M. Hildrew, MD[9], Tae W. Kim, MD, MEHP[10], Robin M. Lloyd, MD[11], Sanjay R. Parikh, MD[12], Stanford T. Shulman, MD[13], David L. Walner, MD[14], Sandra A. Walsh[6], and Lorraine C. Nnacheta, MPH[15]

AMERICAN ACADEMY OF OTOLARYNGOLOGY-HEAD AND NECK SURGERY FOUNDATION

SAGE

Mitchell 2019

Current Guidelines

5. Indications for polysomnography	Before performing tonsillectomy, the clinician should refer children with obstructive sleep-disordered breathing (oSDB) for polysomnography (PSG) if they are <2 years of age or if they exhibit any of the following: obesity, Down syndrome, craniofacial abnormalities, neuromuscular disorders, sickle cell disease, or mucopolysaccharidoses.	Recommendation
6. Additional recommendations for polysomnography	The clinician should advocate for polysomnography (PSG) prior to tonsillectomy for obstructive sleep-disordered breathing (oSDB) in children without any of the comorbidities listed in Key Action Statement 5 for whom the need for tonsillectomy is uncertain or when there is discordance between the physical examination and the reported severity of oSDB.	Recommendation
7. Tonsillectomy for obstructive sleep apnea	Clinicians should recommend tonsillectomy for children with obstructive sleep apnea (OSA) documented by overnight polysomnography (PSG).	Recommendation
2. Inpatient monitoring for children after tonsillectomy	Clinicians should arrange for overnight, inpatient monitoring of children after tonsillectomy if they are <3 years old or have severe obstructive sleep apnea (OSA; apnea-hypopnea index [AHI] ≥10 obstructive events/hour, oxygen saturation nadir <80%, or both).	Recommendation

Mitchell 2019

Current Guidelines

Table 6. Role of PSG in Assessing High-Risk Populations before Tonsillectomy for oSDB.

Role of PSG	Rationale
Avoid unnecessary or ineffective surgery in children with primarily nonobstructive events	Identify primarily nonobstructive events or central apnea that may not have been suspected prior to the study and may not benefit from surgery
Confirm the presence of obstructive events that would benefit from surgery	The increased morbidity of surgery in high-risk children requires diagnostic certainty before proceeding
Define the severity of oSDB to assist in preoperative planning	Children with severe OSA may require preoperative cardiac assessment, pulmonary consultation, anesthesia evaluation, or postoperative inpatient monitoring in an intensive care setting
Provide a baseline PSG for comparison after surgery	Persistent OSA despite surgery is more common in high-risk patients than in otherwise healthy children
Document the baseline severity of oSDB	High-risk patients are more prone to complications of surgery or anesthesia

Abbreviations: OSA, obstructive sleep apnea; oSDB, obstructive sleep-disordered breathing; PSG, polysomnography.

Mitchell 2019

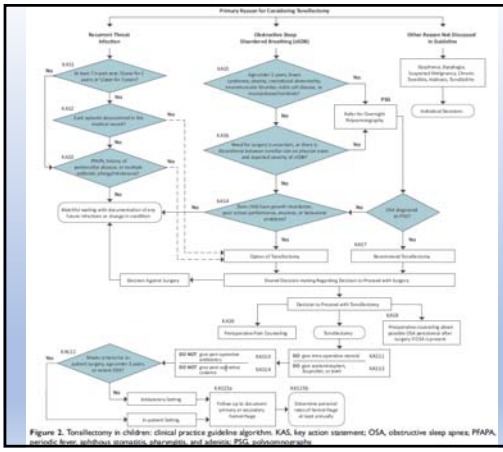


Figure 2. Tonsillectomy in children: clinical practice guideline algorithm. KAS, key action statement; OSA, obstructive sleep apnea; PFAPA, periodic fever, aphthous stomatitis, pharyngitis, and adenitis; PSG, polysomnography.

Mitchell 2019

Previous Guidelines

Guideline

Clinical Practice Guideline: Polysomnography for Sleep-Disordered Breathing Prior to Tonsillectomy in Children

Peter S. Roland, MD[1], Richard M. Rosenfeld, MD, MPH[2], Lee J. Brooks, MD[3], Norman R. Friedman, MD, DABSM[4], Jacqueline Jones, MD[5], Tae W. Kim, MD[6], Siobhan Kuhar, MD, PhD, DABSM[7], Ron B. Mitchell, MD[8], Michael D. Seidman, MD[9], Stephen H. Sheldon, DO[10], Stephanie Jones[11], and Peter Robertson, MPA[11]

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SAGE

Roland 2011

Previous Guidelines

Table 1. Summary of Action Statements for PSG

Statement	Action	Evidence
1. Indications for PSG	Before performing tonsillectomy, the clinician should refer children with SDB for PSG if they exhibit any of the following: obesity, Down syndrome, craniofacial abnormalities, neuromuscular disorders, sickle cell disease, or mucopolysaccharidoses.	Recommendation based on observational studies with a preponderance of benefit over harm.
2. Advocating for PSG	The clinician should advocate for PSG prior to tonsillectomy for SDB in children without any of the comorbidities listed in statement 1 for whom the need for surgery is uncertain or when there is discordance between tonsillar size on physical examination and the reported severity of SDB.	Recommendation based on observational and case-control studies with a preponderance of benefit over harm.
3. Communication with anesthesiologist	Clinicians should communicate PSG results to the anesthesiologist prior to the induction of anesthesia for tonsillectomy in a child with SDB.	Recommendation based on observational studies with a preponderance of benefit over harm.
4. Inpatient admission for children with OSA documented in results of PSG	Clinicians should admit children with OSA documented in results of PSG for inpatient, overnight monitoring after tonsillectomy if they are younger than age 3 or have severe OSA (apnea-hypopnea index of 10 or more obstructive events/hour, oxygen saturation nadir less than 80%, or both).	Recommendation based on observational studies with a preponderance of benefit over harm.
5. Unattended PSG with portable monitoring device	In children for whom PSG is indicated to assess SDB prior to tonsillectomy, clinicians should obtain laboratory-based PSG, when available.	Recommendation based on diagnostic studies with limitations and a preponderance of benefit over harm

Abbreviations: OSA, obstructive sleep apnea; PSG, polysomnography; SDB, sleep-disordered breathing.

Roland 2011

Pathophysiologic Consequences of OSA

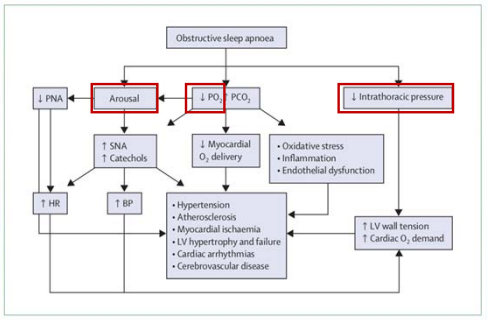
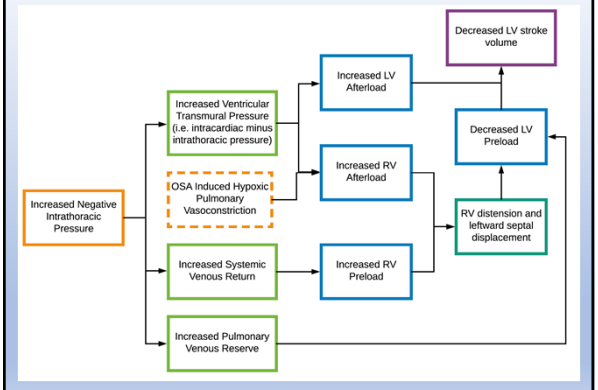


Figure: **Pathophysiological effects of obstructive sleep apnoea on the cardiovascular system**
PNA=parasympathetic nervous system activity. PO_2=partial pressure of oxygen. PCO_2=partial pressure of carbon dioxide. SNA=sympathetic nervous system activity. HR=heart rate. BP=blood pressure. LV=left ventricular.

Bradley 2009



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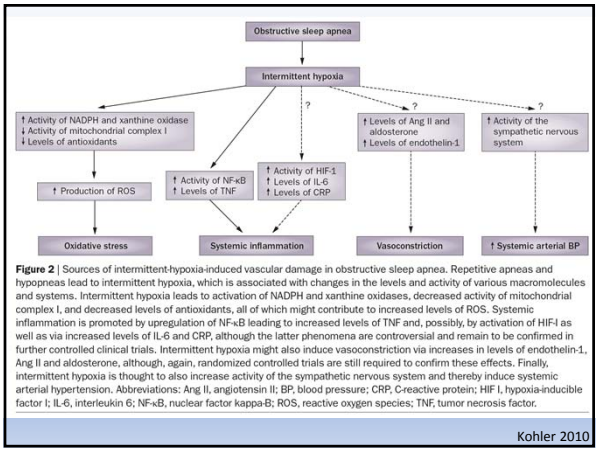


Figure 2 | Sources of intermittent-hypoxia-induced vascular damage in obstructive sleep apnea. Repetitive apneas and hypopneas lead to intermittent hypoxia, which is associated with changes in the levels and activity of various macromolecules and systems. Intermittent hypoxia leads to activation of NADPH and xanthine oxidases, decreased activity of mitochondrial complex I, and decreased levels of antioxidants, all of which might contribute to increased levels of ROS. Systemic inflammation is promoted by upregulation of NF-κB leading to increased levels of TNF and, possibly, by activation of HIF-I as well as via increased levels of IL-6 and CRP, although the latter phenomena are controversial and remain to be confirmed in further controlled clinical trials. Intermittent hypoxia might also induce vasoconstriction via increases in levels of endothelin-1, Ang II and aldosterone, although, again, randomized controlled trials are still required to confirm these effects. Finally, intermittent hypoxia is thought to also increase activity of the sympathetic nervous system and thereby induce systemic arterial hypertension. Abbreviations: Ang II, angiotensin II; BP, blood pressure; CRP, C-reactive protein; HIF I, hypoxia-inducible factor I; IL-6, interleukin 6; NF-κB, nuclear factor kappa-B; ROS, reactive oxygen species; TNF, tumor necrosis factor.

Kohler 2010

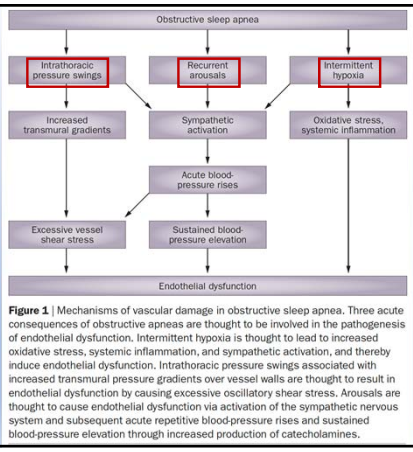


Figure 1 | Mechanisms of vascular damage in obstructive sleep apnea. Three acute consequences of obstructive apneas are thought to be involved in the pathogenesis of endothelial dysfunction. Intermittent hypoxia is thought to lead to increased oxidative stress, systemic inflammation, and sympathetic activation, and thereby induce endothelial dysfunction. Intrathoracic pressure swings associated with increased transmural pressure gradients over vessel walls are thought to result in endothelial dysfunction by causing excessive oscillatory shear stress. Arousals are thought to cause endothelial dysfunction via activation of the sympathetic nervous system and subsequent acute repetitive blood-pressure rises and sustained blood-pressure elevation through increased production of catecholamines.

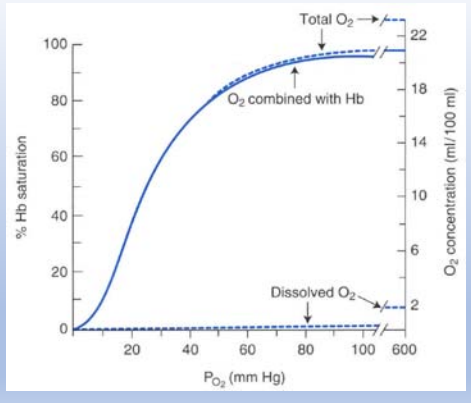
Kohler 2010

Are oxygen desaturations of pathologic consequence if their nadir is >90%?

What is the desaturation duration that is of pathologic consequence?

Reasons to Consider these Questions:

- I've suggested that intermittent hypoxemia is a driving insult behind the pathology associated with OSA – So, what is the definition of intermittent hypoxemia?
- Allows us to briefly discuss the methodology that has been used to generate the previous figures
- Helps us understand why clinical studies tend to focus on the AHI rather than the ODI
- Frequent clinical question – On our sleep studies we report desaturations that are often **not** recorded, or **deemed insignificant** by home oximetry and standard inpatient monitoring



West 2016

Are oxygen desaturations of pathologic consequence if their nadir is >90%?

Studies on isolated intermittent hypoxemia:

- Most of these studies exposed animals to low FiO2 (<0.07) and did not monitor SpO2 or PaO2. Others used SpO2 desaturations with a wide delta and nadir <90%.

Studies on intermittent hypoxemia with obstructive events

- Several studies have demonstrated significant correlation between the AHI and OSA comorbidities regardless of whether a 3% or 4% oxygen desaturation was used to score hypopneas. These conclusions were reached despite not having a required SpO2 nadir.
  - Potential interpretations include:
    - Oxygen desaturations with a small delta and SpO2 nadir >90% contribute significantly to the pathophysiology of OSA
    - The unreported SpO2 nadirs in these studies were more significant than presumed, and are required to cause pathology
    - Other obstructive phenomenon are driving the pathophysiology of OSA in these cases

Bass 2004; Berry 2012; Kohler 2010

What is the desaturation duration that is of pathologic consequence?

- No uniform duration used in studies of isolated intermittent hypoxemia
  - Duration of exposure to FiO2 <0.21 standardized, but duration of time with SpO2 drop not standardized
- Risk stratification for duration of desaturation not performed in studies of intermittent hypoxemia with obstructive events
- AASM Scoring Manual and guideline papers elude to the significance of short desaturations: "use pulse oximetry with a maximum acceptable signal averaging time of ≤ 3 seconds at a heart rate of 80 beats per minute."
  - *Equates to ≤ 4 beat averaging time*

Bass 2004; Berry 2018; Kohler 2010; Redline 2007

Moving Forward with Oxygen Desaturations

- Direct consequences of oxygen desaturations with a nadir >90% remain unclear
- Duration of oxygen desaturation required to cause pathology remains unclear
- The AASM has developed specific definitions for apneas and hypopneas, which have been consistently adopted by researchers
- The cut-points that have been set for the apnea/hypopnea definitions may not be the natural line between normal and pathology, but they give us somewhere to start, particularly standardization amongst researchers
- In theory the AHI value takes into account all insults that are associated with obstructive apneas and hypopneas

➢For these reasons the clinical outcomes of OSA have been more clearly associated with AHI values, than ODI values

Neurodevelopmental Outcomes

Louisville & Chicago Cohort Study on Neurodevelopmental Outcomes

Table 1. General Characteristics of the Four Groups of Children Based on the Presence or Absence of Habitual Snoring and Their Polysomnographically Derived Apnea–Hypopnea Indices

	Group 1 Nonsnoring AHI <1/h TST (*n* = 90)	Group 2 Snoring AHI <1/h TST (*n* = 431)	Group 3 Mild OSA AHI ≥1/h and <5/h TST (*n* = 348)	Group 4 OSA AHI ≥5/h TST* (*n* = 141)	*P* Value
Age, yr	6.86 (0.70)	6.81 (0.70)	6.82 (0.82)	6.69 (1.02)	0.480
Male sex, %	56.67%	54.99%	53.16%	56.03%	0.899
Race					<0.001†
White, n	67 (74.44%)	273 (63.34%)	200 (57.47%)	48 (30.04%)	
African American, n	13 (14.44%)	119 (27.61%)	100 (28.74%)	72 (51.06%)	
BMI *Z* score	0.46 (1.33)	0.65 (1.26)	0.73 (1.42)	1.25 (1.53)	<0.001†
Total sleep duration, min	469.17 (47.74)	472.62 (43.79)	472.03 (48.07)	460.21 (55.16)	0.055
Sleep efficiency, %	88.75 (8.09)	89.25 (7.63)	90.33 (7.54)	89.63 (8.34)	0.172
Stage 1, %	7.31 (4.98)	6.92 (4.90)	6.59 (6.41)	7.85 (6.48)	0.239
Stage 2, %	44.99 (7.81)	45.87 (7.87)	44.75 (8.56)	44.38 (7.70)	0.137
Stage SWS, %	28.53 (6.83)	26.05 (9.05)	28.96 (9.24)	26.30 (8.64)	0.163
REM sleep, %	24.43 (14.81)	21.57 (8.78)	20.56 (7.59)	21.51 (13.93)	0.059
Sleep latency, min	26.52 (28.84)	23.61 (24.04)	20.93 (21.53)	18.04 (21.60)	0.023
REM latency, min	147.86 (66.37)	141.51 (59.24)	150.22 (68.53)	146.71 (67.62)	0.300
Obstructive AHI, events/h TST	0.40 (0.34)	0.40 (0.29)	2.11 (1.03)	14.87 (12.44)	<0.001†
Sp_{O_2} nadir,‡ %	93.80 (2.35)	92.72 (6.00)	90.27 (5.00)	82.65 (10.94)	<0.001†
Total arousal index, events/h TST	8.56 (3.95)	9.14 (5.77)	10.78 (7.39)	17.51 (11.24)	<0.001†
Asthma, %	14.94	20.45	19.04	24.71	0.430

Definition of abbreviations: AHI = apnea–hypopnea index; BMI = body mass index; OSA = obstructive sleep apnea; Sp_{O_2} = oxygen saturation as measured by pulse oximetry; SWS = slow-wave sleep; TST = total sleep time.
*AHI measured as number of events per hour of total sleep time.
†Comparison is significant following Bonferroni's correction.
‡Sp_{O_2} nadir refers to lowest levels of arterial oxygen saturation in the blood.

Hunter 2016

Table 2. Cognitive Function Differences across Snore Apnea–Hypopnea Levels

Test	Number of Patients	*F* Test Statistic	*P* Value
DAS			
Verbal	977	6.58	<0.001*
Nonverbal	975	5.01	0.002*
Global	985	7.51	<0.001*
NEPSY			
Design Copying	1001	6.27	0.001*
Phonological Processing	1001	3.38	0.019
Tower	1003	8.39	<0.001*
Speed Naming	958	2.45	0.048
Arrows	978	11.65	<0.001*
Visual Attention	968	4.68	0.004
Comprehension	977	7.14	<0.001*
PPVT	580	1.18	0.383
EVT	557	2.90	0.040

Definition of abbreviations: DAS = Differential Ability Scales; EVT = Expressive Vocabulary Test; NEPSY = a Developmental Neuropsychological Assessment; PPVT = Peabody Picture Vocabulary Test.
*Omnibus comparison is significant after Bonferroni's correction for multiple comparisons.

Hunter 2016

Meta-Analysis: ADHD symptoms and OSA

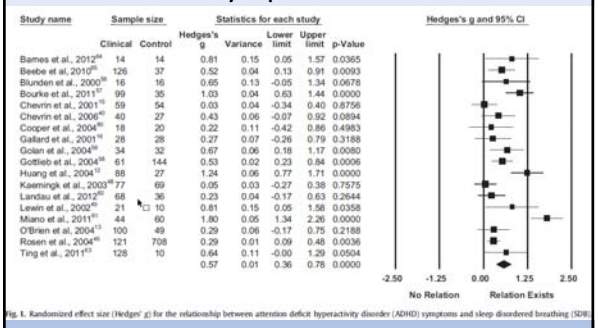


Fig. 1. Randomized effect size (Hedges' g) for the relationship between attention deficit hyperactivity disorder (ADHD) symptoms and sleep disordered breathing (SDB).

Sedky 2014

ADHD Symptoms Before & After T&A

TABLE 2 Polysomnographic Measures of SDB (Mean ± SD)

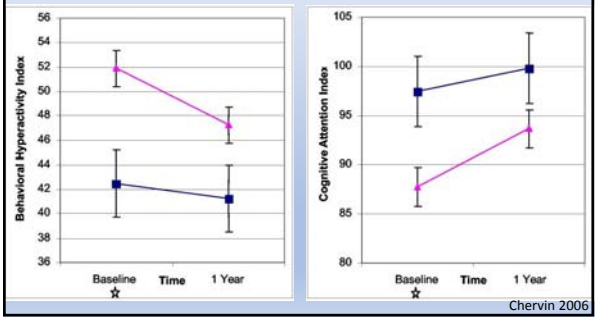
	Baseline			1-y Follow-up		
	AT (*n* = 78)	Control (*n* = 27)	*P* (*t* Test)	AT (*n* = 77)	Control (*n* = 23)	*P* (*t* Test)
Obstructive apnea index	2.9 ± 6.3	0.2 ± 0.4	<.001	0.2 ± 0.3	0.2 ± 0.5	.91
Apnea/hypopnea index	7.3 ± 12.5	1.2 ± 1.9	<.001	1.1 ± 1.1	1.2 ± 1.8	.76
Respiratory disturbance index[a]	7.6 ± 11.3	1.4 ± 2.0	<.001	1.1 ± 0.9	1.8 ± 2.6	.36
Arousal index	12.6 ± 6.4	11.1 ± 5.8	.27	9.8 ± 2.9	10.4 ± 4.5	.58
Minimum oxygen saturation	91.1 ± 7.9	94.2 ± 3.1	.005	93.7 ± 2.6	93.5 ± 2.5	.68
Sleep time spent with end-tidal CO_2 >50 mm Hg, %[b]	36.1 ± 38.6	19.8 ± 35.5	.06	22.0 ± 34.8	10.2 ± 26.5	.15

[a] Available for 54 AT and 22 control subjects at baseline and 42 AT subjects and 13 control subjects at follow-up.
[b] Available for 71 AT and 27 control subjects at baseline and 77 AT subjects and 22 control subjects at follow-up.

Chervin 2006

- The Conners' Parent Rating Scales-Revised and Child Symptom Inventory-4: Parent Checklist were used to generate the behavioral hyperactivity index
- The Integrated Visual and Auditory Continuous Performance Test and Children's Memory Scale were used to generate the cognitive attention index

Triangles = T&A subjects
Squares = control subjects



Chervin 2006

Decreased Quality of Life

Excessive Daytime Sleepiness

TABLE 3 Change Scores in QoL and Symptom Measures by Treatment Arm

Outcome	eAT		WWSC		Effect Size[a]	P^b	P^c
	Baseline	Change	Baseline	Change			
PedsQL (parent) total	77.9 ± 15.4	5.9 ± 13.6	76.7 ± 15.5	0.9 ± 13.3	0.37	<.01	<.01
PedsQL (parent) emotional function	78.2 ± 18.6	4.8 ± 16.7	73.5 ± 19.6	2.1 ± 18.1	0.16	.12	<.01
PedsQL (parent) physical function	80.3 ± 20.5	7.4 ± 19.9	83.1 ± 18.3	−0.7 ± 18.2	0.42	<.01	<.01
PedsQL (parent) school function	74.4 ± 19.6	7.4 ± 18.1	73.2 ± 20.1	0.2 ± 19.7	0.38	<.01	<.01
PedsQL (parent) social function	84.2 ± 19.0	3.2 ± 19.6	81.9 ± 19.3	2.9 ± 17.2	0.02	>.99	.56
PedsQL (child) total	68.3 ± 16.1	3.4 ± 17.3	67.6 ± 14.8	3.3 ± 16.9	0.01	.92	.43
PedsQL (child) emotional function	66.0 ± 23.2	3.9 ± 28.9	64.3 ± 23.5	2.2 ± 29.5	0.06	.55	.07
PedsQL (child) physical function	73.3 ± 18.2	3.0 ± 20.3	73.5 ± 17.0	2.0 ± 22.3	0.05	.63	.58
PedsQL (child) school function	63.1 ± 21.7	4.3 ± 23.9	63.4 ± 19.4	3.5 ± 22.5	0.03	.70	.89
PedsQL (child) social function	68.3 ± 24.8	2.8 ± 26.1	64.0 ± 24.2	7.0 ± 26.2	−0.16	.12	.65
OSA-18 total	53.1 ± 19.3	−21 ± 16.9	54.1 ± 18.8	−4.5 ± 19.3	−0.93	<.01	<.01
OSA-18 sleep disturbance	3.8 ± 1.4	−2.2 ± 1.3	3.8 ± 1.5	−0.5 ± 1.6	−1.14	<.01	<.01
OSA-18 emotional distress	2.4 ± 1.5	2.1 ± 1.5	2.6 ± 1.8	2.6 ± 1.6	−0.30	<.01	.01
OSA-18 physical suffering	2.7 ± 1.4	−0.8 ± 1.3	2.7 ± 1.3	−0.1 ± 1.5	−0.60	<.01	<.01
OSA-18 daytime problems	2.8 ± 1.4	−1.0 ± 1.3	2.9 ± 1.5	−0.1 ± 1.5	−0.68	<.01	<.01
OSA-18 caregiver concerns	2.8 ± 1.5	−1.2 ± 1.4	3.0 ± 1.5	−0.4 ± 1.6	−0.51	<.01	<.01
PSQ-SRBD total	0.5 ± 0.2	−0.3 ± 0.2	0.5 ± 0.2	−0.0 ± 0.2	−1.35	<.01	<.01
PSQL snoring subscale	0.8 ± 0.3	−0.7 ± 0.3	0.8 ± 0.3	−0.1 ± 0.4	−1.55	<.01	<.01
PSQL sleepiness subscale	0.4 ± 0.3	−0.5 ± 0.4	0.5 ± 0.3	−0.0 ± 0.4	−0.65	<.01	<.01
PSQL behavior subscale	0.4 ± 0.3	−0.1 ± 0.3	0.5 ± 0.3	−0.0 ± 0.3	−0.34	<.01	<.01
SLSC total (mESS)	7.1 ± 4.7	−2.0 ± 4.2	7.5 ± 5.2	−0.3 ± 4.1	−0.42	<.01	<.01

[a] Cohen's d.
[b] Adjusting stratified variables only: site, race (African American versus non-African American), age (0–7 vs 8–10 years old), and overweight (≥83th vs <83th BMI percentile).
[c] Adjusting for site, race (African American versus non-African American), age (continuous), obese, gender, maternal education (less than high school, high school or higher, or missing/not sure), income (<$30 000, ≥$30 000, or missing), baseline AHI quartile, and baseline outcome variable.

- Effect sizes calculated by Cohen's d; relates the magnitude of group difference to the standard deviation
- >0.20 to 0.49 small effect size; 0.50 to 0.79 medium effect size; and ≥0.80 large effect size

Garetz 2015

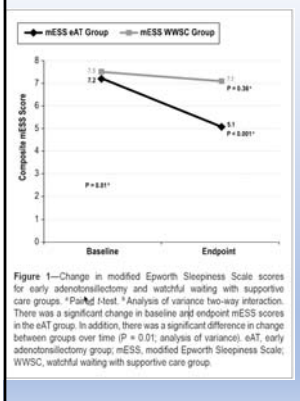


Figure 1—Change in modified Epworth Sleepiness Scale scores for early adenotonsillectomy and watchful waiting with supportive care groups. †Paired t-test. *Analysis of variance two-way interaction. There was a significant change in baseline and endpoint mESS scores in the eAT group. In addition, there was a significant difference in change between groups over time (P = 0.01; analysis of variance). eAT, early adenotonsillectomy group; mESS, modified Epworth Sleepiness Scale; WWSC, watchful waiting with supportive care group.

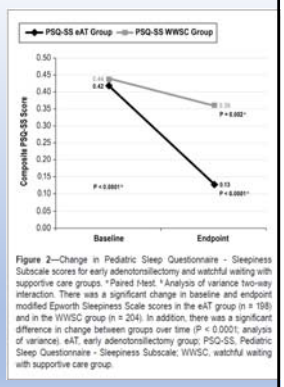


Figure 2—Change in Pediatric Sleep Questionnaire - Sleepiness Subscale scores for early adenotonsillectomy and watchful waiting with supportive care groups. †Paired t-test. *Analysis of variance two-way interaction. There was a significant change in baseline and endpoint modified Epworth Sleepiness Scale scores in the eAT group (n = 198) and in the WWSC group (n = 204). In addition, there was a significant difference in change between groups over time (P < 0.0001; analysis of variance). eAT, early adenotonsillectomy group; PSQ-SS, Pediatric Sleep Questionnaire - Sleepiness Subscale; WWSC, watchful waiting with supportive care group.

Paruthi 2016

TABLE 1. Demographic Data of Study Population

	Patients With S-SDB	Controls
N	108	72
Age, y, mean ± SD (range)	7 ± 4 (2–16)	8 ± 4 (2–17)
Female gender, *n* (%)	58 (55)	43 (60)
Race, *n* (%)		
White	26 (24)	26 (36)
Black	79 (73)	46 (64)
Other	3 (3)	0 (0)
Private insurance, *n* (%)	37 (34)	28 (39)

There was no statistical difference between patients with S-SDB and control subjects on the basis of age, gender, race, and type of insurance. The type of insurance was used as a surrogate measure of socioeconomic status.

- Modified Epworth sleepiness scale (ESS) completed by parent/caregiver
  - ESS > 10 equates to excessive sleep propensity
- Mean ESS score was significantly higher in S-SDB group vs. control group (8.1 ± 4.9 vs 5.3 ± 3.9; P < 0.001)

Melendres 2004

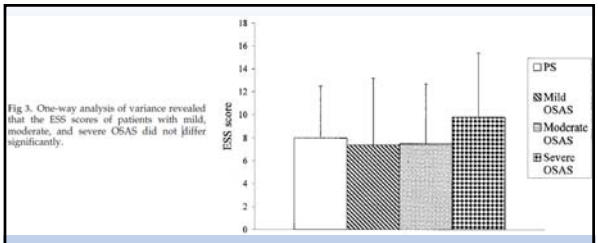


Fig 3. One-way analysis of variance revealed that the ESS scores of patients with mild, moderate, and severe OSAS did not differ significantly.

- Mild OSAS: obstructive AI = 1-4
- Moderate OSAS: obstructive AI = 5-9
- Severe OSAS: obstructive AI ≥ 10

Melendres 2004

Elevated Blood Pressure

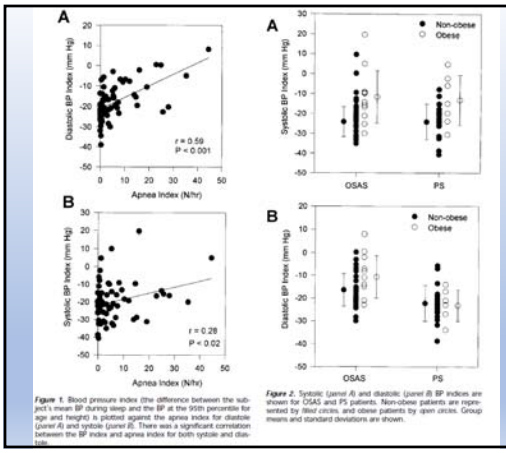


Figure 1. Blood pressure index (the difference between the subject's mean BP during sleep and the BP at the 95th percentile for age and height) is plotted against the apnea index for diastole (panel A) and systole (panel B). There was a significant correlation between the BP index and apnea index for both systole and diastole.

Figure 2. Systolic (panel A) and diastolic (panel B) BP indices are shown for OSAS and PS patients. Non-obese patients are represented by filled circles, and obese patients by open circles. Group means and standard deviations are shown.

Marcus 1998

Table 2. Percentages of BP Measurements Exceeding the 95th Percentile

Variables	Control	Mild	Severe	*P*
% SBP>95th during 24-hour period	10.4 (15.0)	13.0 (17.0)	22.4 (22.3)	<0.001
% DBP>95th during 24-hour period	6.1 (8.9)	7.4 (9.1)	9.7 (8.0)	0.005
% SBP>95th during wake only	15.5 (21.0)	19.7 (25.2)	32.2 (28.4)	<0.001
% DBP>95th during wake only	9.4 (13.3)	12.4 (15.9)	16.2 (14.0)	0.002
% SBP>95th during sleep only	1.3 (7.9)	2.3 (7.8)	5.3 (17.1)	0.002
% DBP>95th during sleep only	0.9 (6.2)	0.7 (3.4)	1.2 (4.3)	0.641

Results are expressed as mean ± SD. *P* = overall *P* for the trend.

- Also, 6% of the healthy controls, 15% of the children with mild OSA, and 29% of the children with severe OSA had mean 24-hour systolic blood pressures greater than the 95th percentile (P=0.01).

Amin 2008; Shamsuzzaman 2014

Does treating OSA improve blood pressure?

Table 2
24-h ABP parameters before and after surgery, $n = 42$.

Parameters	Pre-operative	Post-operative	p-value
Overall systolic mean BP (mm Hg)			
Overall diastolic mean BP (mm Hg)			
Wake systolic mean BP (mm Hg)			
Wake diastolic mean BP (mm Hg)			
Sleep systolic mean BP (mm Hg)			
Sleep diastolic mean BP (mm Hg)			
Wake systolic BP index	0.83 (0.05)	0.84 (0.06)	0.439
Wake diastolic BP index	0.81 (0.06)	0.82 (0.06)	0.565
Sleep systolic BP index	0.89 (0.07)	0.90 (0.08)	0.164
Sleep diastolic BP index	0.92 (0.09)	0.92 (0.09)	0.867
Overall systolic BP load (%)	11.23 (18.75)	6.37 (9.41)	0.065
Overall diastolic BP load (%)	**15.85 (18.22)**	**10.46 (10.16)**	**0.021***
Wake systolic BP load (%)	7.14 (16.56)	4.77 (9.30)	0.325
Wake diastolic BP load (%)	10.93 (18.59)	7.41 (12.33)	0.162
Sleep systolic BP load (%)	19.17 (24.66)	12.65 (20.27)	0.091
Sleep diastolic BP load (%)	26.83 (23.09)	19.80 (19.30)	0.079

Data are presented as mean ± standard deviation (SD) or number (%).
* $p < 0.05$.

To allow comparison between different age groups, blood pressure index (BPI) was calculated: BPI = measured mean BP/95th percentile pressure for sex, age and height.

Ng 2010

Table 4
Subgroup analysis for 24-h ABP parameters before and after AT.

Parameters	Nocturnal hypertensive, $n = 8$			Nocturnal non-hypertensive, $n = 36$		
	Pre-operative	Post-operative	p-value	Pre-operative	Post-operative	p-value
Mean systolic BPI during wake period	0.91 (0.03)	0.88 (0.05)	0.192	0.82 (0.04)	0.83 (0.05)	0.157
Mean diastolic BPI during wake period	0.89 (0.04)	0.87 (0.04)	0.211	0.79 (0.05)	0.81 (0.06)	0.052
Mean systolic BPI during sleep period	1.00 (0.05)	0.93 (0.07)	0.001*	0.87 (0.04)	0.90 (0.09)	0.033*
Mean diastolic BPI during sleep period	1.04 (0.06)	0.94 (0.06)	0.005*	0.89 (0.07)	0.91 (0.10)	0.146
Overall systolic BP load (%)	36.44 (30.2)	9.39 (9.91)	0.014*	5.63 (8.46)	5.69 (9.31)	0.970
Overall diastolic BP load (%)	35.86 (26.64)	11.50 (9.83)	0.016*	11.41 (12.41)	10.23 (10.83)	0.435
Wake systolic BP load (%)	25.44 (32.72)	9.81 (15.16)	0.194	3.07 (5.41)	3.65 (7.29)	0.675
Wake diastolic BP load (%)	23.98 (34.35)	6.95 (5.60)	0.156	8.03 (11.87)	7.51 (13.43)	0.754
Sleep systolic BP load (%)	54.53 (27.93)	15.83 (20.34)	0.001*	11.32 (15.55)	11.94 (20.48)	0.854
Sleep diastolic BP load (%)	57.69 (19.95)	23.94 (17.54)	0.003*	19.97 (17.58)	18.88 (19.78)	0.778
BMI z-score	1.59 (1.04)	1.38 (1.03)	0.091	1.04 (1.68)	1.04 (1.27)	0.999
No. of obese children[a]	4	2	0.500	10	12	0.625
No. of hypertensive children[b]	8	2	--	0	8	--

Data are presented as mean ± standard deviation (SD) or number (%).
[a] By McNemar Test.
* Significant difference observed by paired t-test, $p < 0.05$.

Ng 2010