Outcomes in Children with Down Syndrome and Mild Obstructive Sleep Apnea Treated Non-Surgically

Javier J.M. Howard, MD, MPH, **Kathleen M. Sarber, MD**, **Wenwen Yu, MD**, **David F. Smith, MD, PhD**, **Raisa O. Tikhtman, MD**, **Narong Simakajornboon, MD**, **Stacey L. Ishman, MD, MPH**

Department of Otolaryngology–Head and Neck Surgery (D.F.S., S.L.I.), the College of Medicine (J.J.M.H., R.O.T.), University of Cincinnati, Cincinnati, Ohio, U.S.A.; the Division of Pulmonary Medicine (K.M.S., W.Y., D.F.S., N.S., S.L.I.), and the Division of Pediatric Otolaryngology–Head and Neck Surgery (K.M.S., D.F.S., S.L.I.), Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, U.S.A.; and the Department of Oral and Craniomaxillofacial Surgery (W.Y.), Ninth People's Hospital, Shanghai Jiao Tong University, Shanghai, China.

Abstract

Objectives: Nasal steroids, oral anti-leukotrienes and supplemental oxygen are effective in the treatment of mild obstructive sleep apnea (OSA) in otherwise healthy children. However, their efficacy is unknown in children with Down syndrome (DS). Here we examine the effect of single medication therapy versus observation versus oxygen on polysomnographic outcomes in these children.

Methods: We reviewed children (<18 years) diagnosed with DS and mild OSA (obstructive apnea-hypopnea index [oAHI] 1 to <5 events/hour) treated non-surgically (with supplemental oxygen, one medication, or observation) between 2012 and 2017. Demographic data, comorbid diagnoses, and pre- and posttreatment polysomnograms were analyzed. We assessed pre- and posttreatment oAHI, oxyhemoglobin saturation nadir, percent total sleep time (%TST) in rapid eye movement (REM), and end-tidal carbon dioxide ($ETCO_2$) >50 mmHg.

Results: Twenty-four children met inclusion criteria; 10 treated with medication, one with oxygen, and 13 with observation (baseline oAHI was 3.5, 3.3, and 2.9 events/hour, respectively). There was no significant change in oAHI, oxyhemoglobin saturation nadir, $ETCO_2$, or percent TST in REM after treatment for any treatment group (P = .21–.94). There was no association between reported symptoms and AHI severity or change in AHI. OSA resolved in one patient treated with observation and two treated with medication, but worsened in two each in the medication and observation groups. Resolution of OSA occurred in 20% treated with medication, 7.7% with observation, and 0% with oxygen (P = .82).

Conclusion: In our cohort, resolution of mild OSA was low. This suggests that consideration should be given to multimodality treatments in children with DS and mild OSA. Prospective studies will help establish effectiveness in this cohort.

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Keywords

Obstructive sleep apnea; mild; observation; infant; pediatric; children; medication

INTRODUCTION

Down syndrome (DS), defined as having an additional copy of chromosome 21, is the most common genetic disorder, occurring in one in 691 births.[1] Individuals with DS are at an increased risk of a myriad of medical conditions, including obstructive sleep apnea (OSA). Higher than the 1% to 6% prevalence in the general population of children, the prevalence of OSA is DS children is estimated to be between 30% and 50%.[2,3] This prevalence grows with age, as >90% of DS adults are estimated to have OSA.[4] Additionally, individuals with DS tend to have a more severe OSA phenotype, including significant hypoxemia and hypoventilation, when compared to those without DS.[4] Several anatomic factors present in DS children increase the likelihood of upper airway obstruction including a higher prevalence of maxillary and mandibular hypoplasia, relative macroglossia, lingual tonsillar hypertrophy, pharyngeal hypotonia, laryngomalacia, subglottic and tracheal stenosis, and obesity than in the general population.[5–13] Additionally, comorbid medical conditions with increased prevalence in DS individuals like gastroesophageal reflux (GERD) and hypothyroidism can increase the likelihood of OSA development through airway narrowing secondary to inflammation and mucopolysaccharide deposition, respectively.[14–17]

Many of the manifestations of OSA in DS children, including snoring and poor sleep quality, overlap with OSA among children in the general population. However, symptoms more likely to be prominent in DS OSA include failure to thrive, hyperactivity, behavioral disruptions, and poor school performance.[18]

OSA in children has been associated with numerous sequelae including cardiovascular disease, metabolic syndrome, and neurocognitive dysfunction.[19] Additionally, OSA can exacerbate preexisting medical conditions common in DS children such as congenital heart disease and neurocognitive dysfunction. Some studies have found that DS children with OSA performed worse on cognitive testing than DS children without OSA.[20]

While adenotonsillectomy (AT) is the mainstay of OSA treatment in children, normalization of PSG abnormalities following AT in children with DS is low. The aim of this study is to review different treatment modalities in children with DS and mild OSA and their respective effects on polysomnographic parameters.

METHODS

We performed a retrospective chart review of all children (<18 years of age) with DS and mild OSA who were treated non-surgically from 2012 to 2017 at Cincinnati Children's Hospital Medical Center. We defined mild OSA as an obstructive apnea-hypopnea index (oAHI) 1 and <5 events/hour diagnosed by overnight polysomnogram (PSG). Patients were included if they were treated with a single modality (one medication or supplemental oxygen) or observation within 1 year of baseline PSG and had a follow-up PSG. Responders were defined as children whose oAHI was <1 event per hour on the follow-up PSG. Patients without a follow-up PSG or with PSGs less than 3 months apart were excluded. Patients were also excluded if they had a history of prior surgical intervention for OSA (ie, adenotonsillectomy), neuromuscular disease, current tracheostomy, or chronic interstitial lung disease.

Demographic data and additional comorbid diagnoses were collected. Body mass index (BMI) percentile was determined based on Centers for Disease Control and Prevention calculation for age and gender for children >2 years of age. PSG outcomes were recorded for baseline and follow-up apnea-hypopnea index (AHI), oAHI, oxyhemoglobin saturation nadir, percentage of total sleep time spent (%TST) with end-tidal carbon dioxide ($ETCO_2$) >50 mmHg, sleep efficiency (SE), arousal index, and percentage of TST spent in REM sleep (%REM). Baseline and follow-up visits were reviewed to document patient or parent sleep-related complaints of snoring, gasping, breathing pauses, heavy breathing, noisy breathing, nocturnal enuresis, daytime behavior problems, sleepiness, or morning headaches. This study was approved by the institutional review board at the Cincinnati Children's Hospital Medical Center.

Polysomnography

All overnight PSGs were performed in an accredited sleep center within Cincinnati Children's Hospital Medical Center. Standard PSG parameters were recorded simultaneously, including: body position, bilateral electrooculogram (ROC/A1, LOC/A2), six-channel electroencephalogram (EEG; F3A2, F4A1, C3A2, C4A1, O1A2, O2A1), chin electromyogram, anterior tibialis electromyogram, tracheal microphone, electrocardiogram, pulse oximetry, thoracic and abdominal inductance plethysmography, nasal pressure transduction, and end-tidal CO_2 ($ETCO_2$) (BCI Capnoguard, OH). If $ETCO_2$ did not plateau and/or if malfunction of the monitoring cannulas occurred, the $ETCO_2$ was deemed unreliable and it was not included in scoring (capillary blood gases were obtained in these instances). Scoring of the PSG was performed with standard criteria as defined by the American Academy of Sleep Medicine.[21] Sleep stage and respiratory scoring were performed by a certified sleep technician and interpreted by a board-certified sleep physician. An obstructive apnea was defined as a cessation or decrease in in the oronasal thermal airflow tracing by >90% of the pre-event baseline tracing with retained effort throughout the episode. An obstructive hypopnea was defined as a decrease in the peak excursion of the nasal pressure transducer by 30% when compared with the preceding baseline tracing and was associated with an oxygen desaturation 3%, an arousal, or an awakening. All obstructive events were 2 breaths' duration. The number of apneas and

hypopneas (including central and mixed) per hour were calculated and reported as the AHI. The oAHI was defined as the number of obstructive or mixed apneas and hypopneas per hour. Mild OSA was defined as an oAHI ≥ 1 and < 5 events/hour. Oxygen nadir was determined by the lowest oxygen saturation data point during an obstructive event.

Statistical Analysis

Descriptive statistics were used to examine the demographic data. Data distributions were reported as medians with 95% confidence intervals (CI) for continuous variables and frequencies with percentages for categorical variables. The changes in PSG respiratory and EEG parameters between baseline and follow-up were analyzed using the Wilcoxon signed rank test. Changes in categorical variables were tested using the McNemar test.

RESULTS

Forty-eight patients with mild OSA and Down syndrome were identified during the study. Seventeen patients were excluded due to lack of follow-up PSG. Seven patients were excluded because they were treated with both a leukotriene-inhibitor and a nasal steroid spray. Twenty-four children met inclusion criteria: 10 treated with medication, one with oxygen, and 13 with observation. Fourteen of 24 (58.3%) were female. Sixteen (66.7%) were white, four (16.7%) were black, and four (16.7%) were identified as "other." Median age of the observation group was 4.4 years, oxygen group was 0.6 years, medication group was 8.6 years ($P = .015$). There were no other significant differences in demographics or comorbidities between the three treatment groups ($P = .1$–0.79). Demographic data can be found in Table I.

Observation

Thirteen patients were managed with observation. Median time between PSGs was 15.6 months. Their median age was 4.4 years (95% CI, 0.2–10.9). Eight of the 13 (61.5%) were female; nine (69.2%) were white, two (15.4%) were black, and two (15.4%) were identified as "other." The median BMI percentile was 86.0 (95% CI, 61.0–99.9). Comorbidities included: cardiac disease (76.9%), laryngomalacia (30.8%), allergies (23.1%), asthma (15.4%), ADHD (15.4%), pulmonary hypertension (12.5%), and hypertension (7.7%).

Sleep-related complaints were recorded upon initial consultation and follow-up in 69.2% (9/13) children. Seven of these nine children had an increase in AHI while two had a decrease in AHI. Snoring was the most common complaint. For those with an increase in AHI, snoring was reported by 71.4% at baseline and decreased to 57.1% at follow-up. For those with a decrease in AHI, snoring was reported by 50.0% at baseline and did not change at follow-up. Two patients had an improvement in symptoms that corresponded to an improvement in the AHI. Table II illustrates each patient's symptoms at the baseline and follow-up visits. Figure 1 demonstrates the percentage of patients with symptoms at baseline and follow-up grouped by change in AHI.

Interval between PSGs was a median of 15.6 months. Median oAHI was 2.9 events/hour at baseline and 3.6 events/hour on follow-up PSG ($P = .60$). Changes in AHI ($P = .60$), oxygen saturation nadir ($P = .80$), sleep efficiency ($P = .32$), arousal index ($P = .46$), %REM sleep (P

= .72), and %TST with ETCO$_2$ > 50 mmHg (P = .9) were not significantly different within the group or between treatment groups (Table III). One (7.7%) patient had resolution of OSA, 10 (76.9%) continued to exhibit mild OSA, and two (15.4%) had worsening to moderate OSA on follow-up PSG.

Medication

Ten patients (50.0% female and 60.0% white) were treated with a single medication: eight (80%) with montelukast and two (20%) with fluticasone. Medication was started at the follow up appointment after baseline PSG and continued until follow up after interval PSG. Median time between PSGs was 15.4 months. The median age of these patients was 8.6 years (95% CI, 1.9–14.3) and the median BMI percentile was 94.0 (95% CI, 65.1–99.9). Comorbidities included: cardiac disease (60.0%), allergies (30.0%), asthma (30.0%), dyslipidemia (30.0%), hypertension (20.0%), and laryngomalacia (20.0%).

Sleep-related complaints were recorded upon initial consultation and follow-up in 70.0% (7/10) children treated with medication; snoring was the most common complaint. Five of these seven children had an increase in AHI and two children experienced a decrease in AHI. For those with an increase in AHI, snoring was reported by 60.0% at baseline and decreased to 40.0% at follow-up. For those with a decrease in AHI, snoring was reported by 100% at baseline and decreased to 50.0% at follow-up. See Table II for individual patient symptoms. Figure 1 illustrates baseline and follow-up symptoms grouped by change in the AHI.

Changes in AHI (P = .24), oAHI (P = .21), oxygen saturation nadir (P = .99), sleep efficiency (P = .15), arousal index (P = .56), %REM sleep (P = .94), and %TST ETCO$_2$ > 50 mmHg (P = .84) were not significantly different. One (10.0%) patient had resolution of OSA, six (60.0%) continued to exhibit mild OSA, and three (30.0%) had severe OSA (oAHI >10) on follow-up PSG.

Oxygen

One patient was treated with supplemental oxygen. She was a 7.2-month-old white female with comorbid diagnoses of hypertension and cardiac disease. Upon initial evaluation she did not exhibit any sleep-related complaints. She was treated with 1/8 liter per minute oxygen for mixed sleep apnea with an oAHI of 3.3 events/hour. After 12 months, her follow-up PSG showed persistent mild OSA with a posttreatment oAHI 1.1 events/h and her parents complained of new snoring and noisy breathing. Table IV illustrates pre- and posttreatment PSG parameters for the entire cohort. Figure 2 demonstrates the baseline and follow-up oAHI for each treatment group.

DISCUSSION

In this study, we report low rates of resolution of mild OSA in a cohort of 24 children with DS treated non-surgically with observation, medication, or supplemental oxygen. Across the entire cohort, only two (8.3%) patients displayed resolution of OSA on follow-up PSG, and five (20.8%) patients had moderate or severe disease on follow-up. Patient symptoms did not correspond to the degree of AHI, and improvement or worsening of symptoms did not

parallel the improvement or worsening of AHI. This is consistent with previous literature that has demonstrated either weak correlation or no correlation between symptoms and sleep apnea severity.[22,23] However, baseline and follow-up symptoms were only available for 72% of the cohort.

Numerous anatomic and neurologic features of children with DS, including oropharyngeal crowding, midface hypoplasia, lymphoid hyperplasia, and generalized hypotonia, contribute to their substantially increased risk of developing OSA compared to healthy children.[10,24] A recent meta-analysis of 18 studies and 1,200 children with DS calculated an OSA (defined by AHI > 1/h) prevalence of 69% (95% CI, 59–77%).[25] OSA severity in children with DS tends to fall within the severe range (AHI ≥ 10/h), with rates as high as 45% to 68% reported among affected individuals.[24–26]

While adenotonsillectomy can yield improvements in AHI and quality of life measures for children with DS and moderate-to-severe OSA, surgical cure rates are lower than in non-DS children.[26–28] Furthermore, a retrospective review of tonsillectomy in 323 children with DS and OSA showed no association between preoperative OSA severity and polysomnographic outcomes including likelihood of disease resolution, underlining the challenge of identifying patients most likely to benefit from surgery.[26] While not curative, continuous positive airway pressure (CPAP) in patients that can tolerate it has immediate benefits for relief of airway obstruction and has been shown to be an effective treatment for children who are either not candidates for adenotonsillectomy or with refractory OSA following surgery.[29] One prospective randomized study demonstrated equivalency of CPAP and adenotonsillectomy on PSG, Epworth Sleepiness Scale-Children, and OSA-18 outcomes at one year follow-up for 80 children with DS or mucopolysaccharidoses and OSA.[28] However, the application of CPAP to children with OSA is limited due to behavioral and neurocognitive factors, and one retrospective study measured a CPAP adherence rate of 50% in 25 children with DS.[30]

The natural history of mild OSA in children has not been clearly elucidated in the general pediatric population nor specifically for children with DS.[31] For children with DS and mild OSA, the benefits of available treatment modalities are unclear and have never been directly investigated. In a retrospective study by Trosman et al. analyzing adenotonsillectomy versus watchful waiting for 62 pediatric patients with mild OSA, a subgroup analyses for 15 syndromic patients (including seven with DS) revealed no significant differences in rates of resolution of OSA on follow up PSG (33% vs. 22%, respectively, $P = .54$) or change in mean AHI (3.08 to 2.03 and 3.31 to 2.84 events/hour respectively, $P = .36$) between the two treatment groups.[32] In our cohort of patients treated with observation, only one patient (7.7%) demonstrated resolution of OSA on follow up PSG, and two patients (15.4%) were found to have OSA worsened to moderate severity. Our low spontaneous resolution rate is consistent with Trosman's study and indicate that the disease in this population may be unlikely to resolve without active intervention.

Anti-inflammatory medications including corticosteroids and montelukast have been shown to effectively treat OSA in otherwise healthy children as both a primary treatment and for residual disease after adenotonsillectomy through several prospective studies. The reduction in AHI ranged from 1 to 4.9 events/hour depending on the study, and the therapies have been

shown to be effective in reducing both apneas and hypopneas.[33–37] Another large retrospective review demonstrated a benefit of combined intranasal corticosteroids and oral montelukast in the treatment of mild OSA among otherwise healthy children, with 62% of patients displaying resolution of OSA on follow up PSG after 12 weeks of treatment.[38] However, no studies to date have evaluated the effect of medication on OSA in the DS population. One retrospective chart review investigated the frequency of OSA in symptomatic children with craniofacial malformations and the polysomnographic effect of treatment. However, only two patients identified in the cohort were treated with medication, and the subgroup results were not reported.[39] Only one patient (10%) in our cohort of patients treated with steroids or montelukast exhibited resolution of OSA on follow up PSG. This significant difference from findings reported previously in the literature for non-DS children aligns with our current understanding of airway obstruction in DS as multifactorial.

Supplemental oxygen helps to reduce nighttime desaturations in children with OSA but does not treat the source of these events. Oxygen therapy in children at risk or with known pulmonary hypertension may be a reasonable option but yields variable reduction of the AHI.[29,40,41] The one patient in our cohort treated with oxygen had comorbid hypertension and cardiac disease, and she displayed persistent mild OSA on follow-up PSG.

There is currently no standard protocol for the treatment of children with mild OSA; thus the decision to treat these patients with medication, surgery, or oxygen versus observation is dependent on the practitioner. At our institution, our treatment protocol is more likely to recommend observation for children with no daytime symptoms. However, assessment of the subjective complaints in this cohort does not suggest that there was a significant difference in daytime or nighttime symptoms between groups as children in the observation group were just as symptomatic as those in the other groups. This may suggest that provider or family preference plays a large role in treatment selection for children with mild OSA.

This study is limited by its retrospective design, which may bias both available clinical and demographic data. Our patient selection process was also limited in that those patients that responded clinically to treatment may have not undergone posttreatment PSG, thereby biasing our results to those that remained symptomatic or concerning. The retrospective design of this study also did not allow for complete data collection of subjective complaints, as only 72% of patients in the cohort had complete baseline and follow-up symptoms documented. Additionally, only 59% of patients with baseline PSG findings underwent a follow-up PSG within 1 year. Some of this was due to lack of follow-up by families, while for others with symptoms resolution, a second PSG was not performed. Therefore, it is likely that the PSG-based resolution rate reported here is artificially low. Another limitation was the statistically significant difference in age between treatment groups; children who were observed were significantly younger than those that were treated with medication, and the patient treated with oxygen was an infant. With a small sample size, it is difficult to determine the reason for this difference. In addition, the medication group was significantly older than the oxygen and observation groups. Studies investigating the neurobehavior effects of mild OSA have been mainly carried out in children of school age and older,[20,42] so perhaps the decision to treat with medications rather than observe was based upon evidence-based concern for worsening functioning. It is also likely that the symptoms and signs that

are commonly elicited during our sleep history (enuresis, behavior changes, snoring, apneic episodes, morning headaches) are more apparent in older children while in younger children these may be considered less concerning or are less common.[43–46] In addition, older children may present due to a teacher's concern for behavior or learning difficulties which is an additional daytime factor which may drive the decision to treat with medication. Finally, only one patient in our cohort was treated with oxygen, so we were unable to draw any conclusions about oxygen treatment in this cohort.

Despite these limitations, our study is the first to assess response to nonsurgical treatment among children with DS and mild OSA and therefore contributes uniquely to the limited body of literature.

CONCLUSION

In our cohort, resolution of mild OSA was low for all treatment groups. These findings are consistent with the current understanding that OSA in children with DS is likely the result of several overlapping abnormalities contributing to obstructive pathology and suggest that a multimodal approach may be most appropriate in this population. Prospective studies will be helpful in the future to establish a better understanding of treatment outcomes in children with DS and mild OSA.

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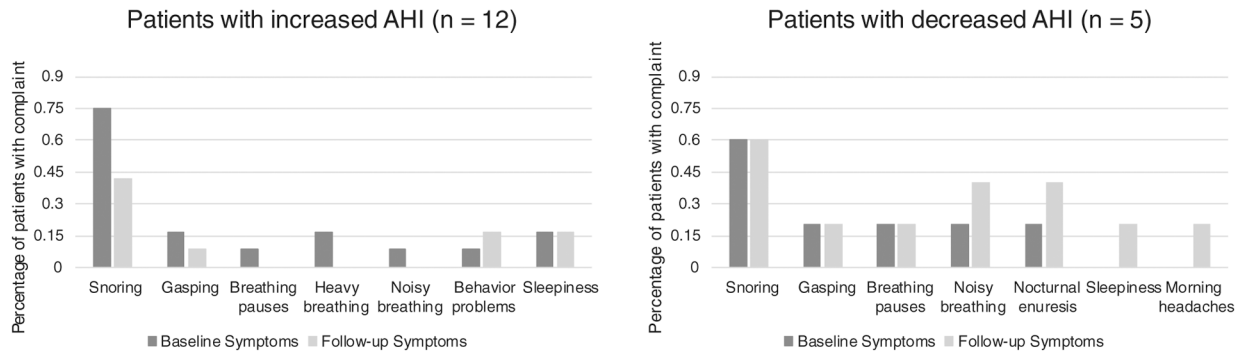
Fig. 1.

Percentage of patients with sleep-related complaints at baseline and follow-up appointments grouped by increase or decrease in AHI.
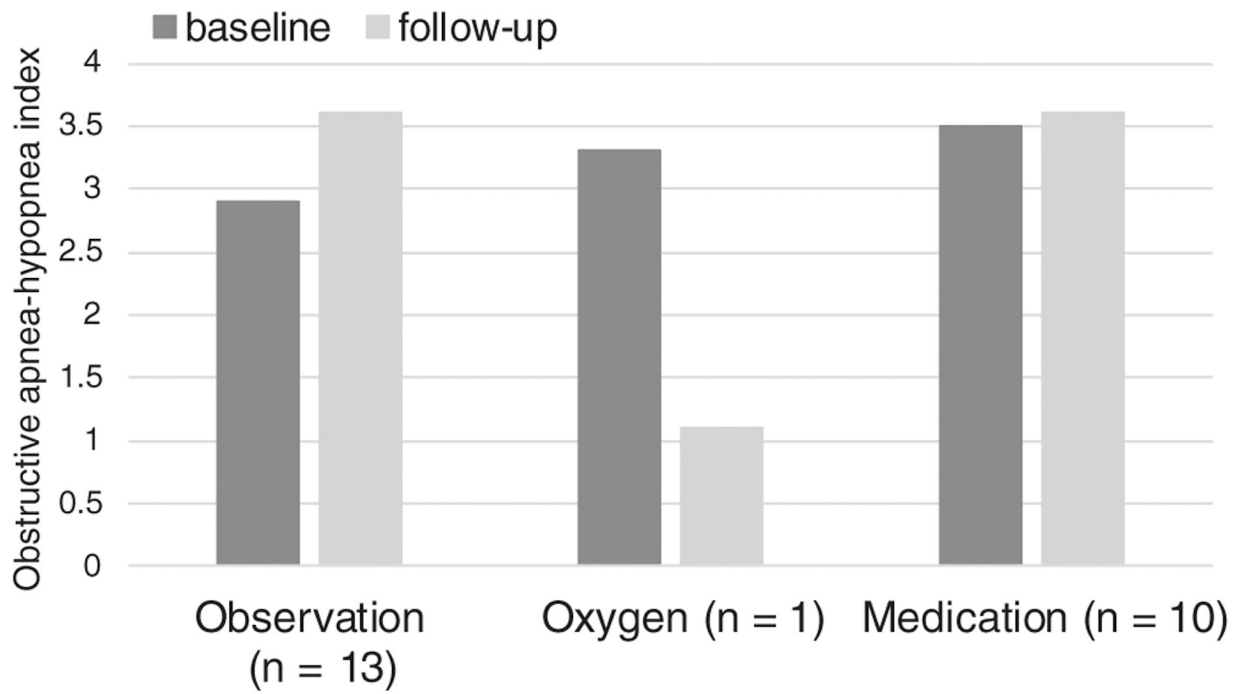
Fig. 2.
Graph of baseline and follow-up obstructive apnea-hypopnea index for children with Down syndrome and mild obstructive sleep apnea treated with medication, supplemental oxygen, or observation.

TABLE I.

Baseline Patient Characteristics for Children with Down Syndrome and Mild Obstructive Sleep Apnea.

Characteristic	Observation (n = 13)	Oxygen (n = 1)	Medication (n = 10)	P
Age, years, median (95% CI)	4.4 (0.2–10.9)	0.6 (–)	8.6 (1.9–14.3)	.015
Sex, female, n (%)	8 (61.5)	1 (100.0)	5 (50.0)	.60
Race, n (%)				.73
White	9 (69.2)	1 (100.0)	6 (60.0)	
Black	2 (15.4)	–	2 (20.0)	
Other	2 (15.4)	–	2 (20.0)	
Body mass index percentile,(95% CI)	86.0 (61.0–99.9)	–	94.0 (65.1–9.9)	.31
Comorbidities, n, (%)*				
Hypertension	1 (7.7)	1 (100.0)	2 (20.0)	.06
Dyslipidemia	0 (0.0)	0 (0.0)	3 (30.0)	.10
Mood disorders	1 (7.7)	0 (0.0)	0 (0.0)	.66
ADHD	2 (15.4)	0 (0.0)	0 (0.0)	.41
Allergies	3 (23.1)	0 (0.0)	3 (30.0)	.79
Asthma	2 (15.4)	0 (0.0)	3 (30.0)	.62
Cardiac disease	10 (76.9)	1 (100.0)	6 (60.0)	.56
Laryngomalacia	4 (30.8)	0 (0.0)	2 (20.0)	.72

ADHD = attention deficit hyperactivity disorder; CI = confidence interval.

TABLE II.

Baseline and Follow-Up Obstructive Apnea-Hypopnea Index and Subjective Sleep-Related Complaints Grouped by Symptom Change for Children with Down Syndrome and Mild Obstructive Sleep Apnea.

| Change in symptoms | Therapy | Appointment type | oAHI | Nocturnal symptoms | | | | | | Daytime symptoms | | |
				Snoring	Gasping	Breath pauses	Heavy breathing	Noisy breathing	Nocturnal enuresis	Behavior problems	Sleepiness	Morning headache
Improved	Observation	Initial	3.4	Yes	Yes			Yes				
		Follow-up	3.9									
	Observation	Initial	2.2	Yes			Yes					
		Follow-up	3.7	Yes								
	Observation	Initial	1.1				Yes			Yes		
		Follow-up	1.4							Yes		
	Observation	Initial	3.7	Yes	Yes	Yes						
		Follow-up	4.5	Yes	Yes							
	Medication	Initial	1.6	Yes								
		Follow-up	1.4									
	Medication	Initial	3.3	Yes								
		Follow-up	3.5									
	Medication	Initial	3.8	Yes								
		Follow-up	1.4									
No Change	Observation	Initial	2.4	Yes							Yes	
		Follow-up	3.6	Yes							Yes	
	Observation	Initial	1.5									
		Follow-up	5.2									
	Medication	Initial	1.3	Yes								
		Follow-up	1.7	Yes								
	Medication	Initial	4.4	Yes								
		Follow-up	11.3	Yes								
	Medication	Initial	3.6									
		Follow-up	13.8									
	Medication	Initial	1.3									
		Follow-up	12.2									

Change in symptoms	Therapy	Appointment type	oAHI	Snoring	Gasping	Nocturnal symptoms				Daytime symptoms		
						Breath pauses	Heavy breathing	Noisy breathing	Nocturnal enuresis	Behavior problems	Sleepiness	Morning headache
Worsened	Observation	Initial	4.9									
		Follow-up	2.9	Yes								
	Observation	Initial	1.8	Yes							Yes	
		Follow-up	1.3	Yes						Yes	Yes	
	Oxygen	Initial	3.3									
		Follow-up	1.1	Yes				Yes				
	Medication	Initial	4.7	Yes	Yes	Yes		Yes	Yes			
		Follow-up	3.6	Yes	Yes	Yes		Yes	Yes		Yes	Yes

oAHI = obstructive apnea-hypopnea index.

Children with an increase in the apnea-hypopnea index are highlighted in grey.

TABLE III.

P-values for Change in Polysomnographic Values with Treatment.

	Observation (n = 13)	Oxygen (n = 1)	Medication (n = 10)
Pre- vs. post oAHI	.60	–	.21
Pre- vs. post-AHI	.60	–	.24
Pre- vs. post-CAI	.81	–	.48
Pre- vs. post-Oxyhemoglobin nadir	.80	–	.99
Pre- vs. post-Sleep Efficiency	.32	–	.15
Pre- vs. post-Arousal Index	.46	–	.56
Pre- vs. post-ETCO$_2$ > 50 mmHg	.90	–	.84
Pre- vs. post-Percentage of REM sleep	.72	–	.94

AHI = apnea-hypopnea index; CAI = central apnea index; ETCO$_2$ = end tidal carbon dioxide; REM = rapid eye movement; oAHI = obstructive apnea-hypopnea index; OSA = obstructive sleep apnea.

TABLE IV.

Polysomnographic Parameters at Baseline and After Treatment for Children with Down Syndrome and Mild Obstructive Sleep Apnea by Treatment Group.

Characteristic	Observation (n = 13)	Oxygen (n = 1)	Medication (n = 10)	P
Baseline parameters				
oAHI, events/hour (95% CI)	2.9 (1.1–4.9)	3.3 (–)	3.5 (1.3–4.7)	.96
AHI, events/hour (95% CI)	3.3 (1.8–7.2)	8.2 (–)	3.5 (1.7–4.7)	.24
CAI, events/hour (95% CI)	0.5 (0–2.3)	4.9 (–)	0.25 (0–2)	.20
Oxyhemoglobin nadir, % (95% CI)	90 (82–96)	73 (–)	89 (80–94)	.22
Sleep efficiency, % total sleep time (95% CI)	83 (62–91)	87	87 (68–95)	.67
Arousal Index, event/hour (95% CI)	14.2 (9.1–32.7)	19.6	10.4 (6.2–18.5)	.18
End-tidal CO_2 > 50 mmHg, min (95% CI)	0.1 (0–62)	0 (–)	0.1 (0–69)	.63
Percentage of REM sleep, % (95% CI)	22 (10–40)	28 (–)	22 (16–28)	.55
Posttreatment polysomnogram parameters				
Posttreatment oAHI, events/hour, (95% CI)	3.6 (0.7–6.8)	1.1 (–)	3.6 (1.5–13.8)	.45
Posttreatment AHI, events/hour (95% CI)	4.1 (0.7–7.8)	4.7 (–)	3.7 (0.8–13.8)	.82
Posttreatment CAI, events/hour (95% CI)	0.4 (0–3.9)	3.6 (–)	0.25 (0–0.6)	.18
Posttreatment oxygen nadir, % (95% CI)	91 (73–95)	85 (–)	90 (73–92)	.25
Posttreatment sleep efficiency, % total sleep time (95% CI)	86 (71–96)	85 (–)	86 (77–98)	.77
Posttreatment Arousal Index, event/hour (95% CI)	12.3 (6.8–24.1)	12.1 (–)	13.3 (6.4–22.5)	.97
Posttreatment CO_2 > 50 mmHg min (95% CI)	0 (0–79)	1.1 (–)	2.8 (0–79)	.47
Posttreatment percentage of REM sleep, % (95% CI)	24 (13–37)	25 (–)	24 (3–38)	.69
Posttreatment OSA severity (n, %)				.82
None	1 (7.7)	0 (0)	1 (10.0)	
Mild	10 (76.9)	1 (100.0)	6 (60.0)	
Moderate/severe	2 (15.4)	0 (0)	3 (30.0)	

AHI = apnea-hypopnea index; CAI = central apnea index; CO_2 = carbon dioxide; REM = rapid eye movement; oAHI = obstructive apnea-hypopnea index; OSA = obstructive sleep apnea.