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Improved Behavior after Adenotonsillectomy In Children with Higher and Lower IQ

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Abstract

Objectives—To examine whether high intellectual ability, in comparison to average or lower performance, reflects the consequences of sleep-disordered breathing and limits behavioral benefit observed 6 months after adenotonsillectomy.

Methods—Children aged 3–12 years (n=147) recruited from otolaryngology practices at two hospitals and assessed with Conners' Parent Rating Scales and an age range-appropriate intellectual measure, the Stanford-Binet Intelligence Scale at baseline and 6 months after clinically-indicated adenotonsillectomy. Subjects were classified as having high (IQ ≥ 110), average (90 ≤ IQ < 110), or low (IQ < 90) cognitive ability.

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Results—After adenotonsillectomy, improvements in Conners' internalizing, externalizing, hyperactivity, and cognitive domains were observed across IQ groups (main effects for time, all $p < .01$ or better), with no evidence for differential improvements among the groups (no significant time by IQ group interactions). The magnitude of behavioral improvement among children with high IQ resembled that observed among the other two groups. Changes in the Conners' domains were not significantly correlated with baseline IQ, age, socioeconomic status, body mass index z-score, or respiratory disturbance index.

Conclusion—Behavioral function can improve after adenotonsillectomy even among children with relatively high intellectual ability at baseline. Diagnosis and treatment of sleep-disordered breathing with expectation of neurobehavioral benefit should be considered among high-performing children as readily as it is more traditionally among their lower-performing peers.

Keywords

Sleep apnea syndrome; Tonsillectomy; Intelligence; Neurobehavioral function

Introduction

Sleep-disordered breathing (SDB) affects 4 to 11 percent of children [1] and is the reason for more than half of all adenotonsillectomies in the United States [2]. Among the most prominent behavioral symptoms that have been associated with SDB in children are daytime inattention, hyperactivity, impulsivity, and cognitive difficulties, which often interfere with children's school performance and family quality of life [3–5]. Differences in manifestations of SDB in children and adults have been reported, with pediatric associations being more associated with hyperactivity, in comparison with adult manifestations of excessive daytime sleepiness [6]. Sleep fragmentation with resultant daytime sleepiness and altered activity in the prefrontal cortex [7] have been proposed as possible contributors to cognitive and behavioral symptoms associated with SDB. In addition, intermittent hypoxemia, as a result of repetitive cessation of breathing during the night has also been considered as a potential causative mechanism for these symptoms [8].

The lay press has emphasized that behavioral symptoms associated with SDB may be ameliorated with adenotonsillectomy in some cases, and recent research has highlighted such improvements in behavior following successful treatment [9–13]. Examples of specific neurobehavioral problems that have been associated with pediatric SDB and studied for improvement after surgery include executive dysfunction, inattention, hyperactivity, Attention-Deficit/Hyperactivity Disorder (ADHD), and aggressive behavior towards peers [12, 14–17].

In practice, many families are advised to consider adenotonsillectomy for childhood SDB, especially when neurobehavioral problems exist at baseline. Clinicians who regularly see children for neurobehavioral problems also are often advised to consider an evaluation to rule out sleep disorders that may at least partly underlie behavioral concerns. Cognitive and behavioral improvements have been found following adenotonsillectomy, even in children with mild SDB [18], and appear maintained over time [19] in parallel with cerebral hemodynamic changes [20]. On the other hand, evidence has also been presented that

academic ability and/or behavior may still be detrimentally affected years following improvements in SDB [21]. Recently, the first randomized multicenter trial of adenotonsillectomy for obstructive sleep apnea in children confirmed robust improvement in behavioral outcomes as assessed by parent and teacher rating scales, though the study could not confirm improvement on cognitive measures of attention or executive functioning [22]. In that study, however, targeted overrepresentation of minorities, exclusion of children with ADHD, and focus on clearly defined obstructive sleep apnea, may have limited cognitive improvement and explained the discrepancy from previous non-randomized studies of children with sleep disordered breathing [23,24].

No previous relevant research, to the authors' knowledge, has focused on possible neurobehavioral improvements following adenotonsillectomy with reference to baseline cognitive status. Children with higher cognitive and intellectual ability levels may be less likely than peers to be screened for occult sleep disorders, if they do not exhibit problems in home or school functioning. They could function better if higher intellectual achievement allows these children to compensate for problems with behavioral regulation. It would be important to address the question of whether children with relatively higher vs. lower intellectual ability show possibly different levels of behavioral benefit after adenotonsillectomy. To evaluate this question, we took advantage of data available from the Washtenaw County Adenotonsillectomy Cohort II [25] to examine whether children with higher cognitive ability at baseline, in comparison to their peers, would demonstrate different neurobehavioral gains six months following surgery.

Methods

Participants

A total of 147 children aged 3 to 12 years old, including 82 boys (56%), were recruited from otolaryngology practices at the University of Michigan Health System in Ann Arbor and St. Joseph Mercy Hospital in Ypsilanti, MI. Children with clinical suspicion of sleep-disordered breathing and scheduled for adenotonsillectomy by their otolaryngologists were eligible for this study. Subjects were excluded for: 1) mental or physical limitations that prevent reasonable interpretation of neurobehavioral tests, 2) medical history that could confound interpretation of EEG or behavioral data, 3) past surgical or current treatment for SDB, or 4) a known medical condition, aside from adenotonsillar hypertrophy, that carries independent high risk of SDB or excessive daytime sleepiness. All participating children provided assent and a parent provided consent for this study, which was approved by the Institutional Review Board (IRBMED) of the University of Michigan. Participants then underwent pre-operative examination of sleep, cognition, and behavior. The same assessments were repeated 6 months after adenotonsillectomy.

Assessment of intellectual functioning and behavior

Children's intellectual functioning was assessed using the 2-subtest abbreviated IQ composite with the Stanford-Binet Intelligence Scale-Fifth Edition (SB:5) [26]. Behavioral symptoms were measured with the Conners' Parent Rating Scales-Revised: Long version [27]. The Stanford Binet, a standardized measure of intellectual ability for age ranges 2

years through adulthood, The abbreviated 'IQ' score is based on two subtests: Fluid Reasoning, and Knowledge. Scores are standardized according to a national normative sample based on age, with a mean of 100 and standard deviation of 15. The Conners' Parent Rating Scales-Revised: Long Version contains 80 items that provide a parent-based approach to the measurement of child behavior between the ages of three and 17 years. Subscales consisting of standardized T-scores were grouped into four separate domains: hyperactivity (including subscales for Hyperactivity, DSM-IV Hyperactive-Impulsive, DSM-IV Inattentive, and Global index of Restless-Impulsive behavior), externalizing (Oppositional and Global Index of Emotional Lability), internalizing (Anxious-Shy, Social Problems, and Perfectionism), and cognitive rating (Cognitive Problems/Inattention), as primary outcome variables [13].

Polysomnography

Polysomnography included 6 electroencephalography (EEG) channels, 2 electrooculography (EOG) channels, chin and bilateral anterior tibialis surface electromyography (EMG), 2 electrocardiography (EKG) leads, nasal and oral airflow (thermocouples), nasal pressure monitoring, snoring, and finger oximetry. All procedures were conducted in accordance with American Academy of Sleep Medicine 2007 recommendations [28], published after the start of this research, except that piezoelectric strain gauges were used rather than inductance plethysmography for monitoring of thoracic and abdominal excursion. Scoring also was performed according to standard guidelines [28] by a single, experienced registered technologist masked to results of patients' clinical assessments and measurements.

Statistical analysis

For the present analyses, children were categorized into three groups based on the summary IQ score following the normative classification of Stanford Binet: below average (IQ<90), average (90 IQ<110), and high average (IQ ≥ 110). Data were summarized as means ± SD. For demographic data, chi-square tests were used for dichotomous variables and one way ANOVAs were used for continuous variables, and post hoc analyses were performed to test for differences in baseline clinical and demographic variables such as age, grade, socioeconomic status, z-score of body mass index, and polysomnographic findings among the three IQ groups. Changes in parent ratings after adenotonsillectomy on the four behavioral domain scores of the Conners' Parent Rating Scales, within specific IQ groups and by gender, were assessed using mixed model repeated measures analyses with IQ group, Gender, and Time (pre-, post-) as independent variables. Spearman correlations were computed to assess associations between clinical variables and improvements in each of the four Conners' behavioral domains. Statistical analyses were performed with SAS Ver. 9.3, which accounts for group size differences at pre- or post-surgery, allowing use of all available data. Post-hoc comparisons were completed using the Least Squares Means procedure and SAS Slice Effects. The level of significance was defined as $p < 0.05$ in 2-tailed tests for all analyses.

Results

Clinical and demographic characteristics of the children are shown in Table 1. Among 147 children, the entire cohort of children recruited, 132 children were underwent the follow up polysomnography study and behavioral assessment after 6 months, and the mean duration from the first to follow up sleep study was 31.2 ± 4.1 weeks (range=23 – 46 weeks). Among all participants, the mean age was 7.2 ± 2.5 years and the average IQ was 100.7 ± 14.9 . No significant differences emerged in age, years of education, or gender between the three IQ groups. The change in IQ for each group was not significant over time ($p = .352$) when adjusted for age and baseline IQ. At baseline the respiratory disturbance index (RDI) exceeded 1.0, a sensitive threshold used to identify pediatric obstructive sleep apnea [29], in 123 children (84%). The RDI and minimum O₂ saturation at baseline were significantly higher and lower, respectively, in the low IQ group than in the average IQ group. The RDI was significantly improved after adenotonsillectomy among all subjects and in each IQ group (all, $p < 0.01$), with no significant difference in RDI or minimum O₂ saturation between the three IQ groups after adenotonsillectomy.

For the Conners' Parent Rating Scale (pre- and post- surgery means presented in Table 2), significant main effects for Time were found for each of the behavioral measures, reflecting improvement in all groups following adenotonsillectomy. No group by time interactions were evident, nor main effects for group, consistent with no significant intergroup or over time differences in behavior (Table 3).

Correlations were examined between change scores in the Conners' domains (follow-up minus baseline) and baseline IQ, age, socioeconomic status, body mass index z-score, and RDI, or changes in RDI. None of these associations were statistically significant.

Discussion

In this cohort study of patients who underwent adenotonsillectomy, we found no evidence that neurobehavioral function improves any less after surgery among children with relatively high intellectual scores at baseline as compared to those with relatively lower intellectual scores. Previous studies have suggested that SDB may be associated with impaired cognitive development in children [13, 30, 31], with concomitant negative effects on children's ability to learn and perform in school. However, whether children with higher relative cognitive ability might benefit from surgery to the same relative degree as those with lower ability has not previously been addressed. Our results did not suggest that treatment for SDB leads to differential improvements in behavior based on baseline IQ ranges. Clinicians should consider surgical treatment for SDB, and anticipate potential behavioral improvement, even when children already show strong cognitive functioning at baseline.

The IQ groups in this study did differ significantly on several demographic and medical factors, including socioeconomic status, body mass index and race at baseline, many of which have been associated with sleep parameters [32,34]. Lower socioeconomic standing has been associated with greater body mass index [35,36] and lower intellect, and higher body mass index has been associated with increased RDI and race. Even given these

differences, no differences or differential changes in behavior were evident across the three IQ groups.

Our finding of no relationships between post-adenotonsillectomy changes in neurobehavioral parameters with sleep-related or demographic variables is consistent with most previous studies [37–39]. Results of the current study add further to this understanding, but now suggesting that change in neurobehavioral functioning also is not associated with baseline intellectual functioning.

A limitation for this study is the comparatively smaller number of subjects in the Low and High IQ groups as compared to the Average IQ group, though this also is to be expected given normal population characteristics. Also, it is possible that fewer high performing children are referred to sleep clinics, because they are doing well at school, and their parents and teachers do not characterize them as having problems to be evaluated. Another possible limitation is that, although the assessments of cognitive status involving one-on-one testing can be considered objective, our main outcomes, derived from behavioral rating scales, are subjective, dependent on parental observations and perhaps expectations [40]. Parental responses, conceivably, can be influenced by factors such as tendencies of respondents to answer all questions with a specific bias or based on certain confounds.

This study provides data that can be important in helping families and clinicians anticipate behavioral change after childhood adenotonsillectomy. As knowledge by both families and medical professionals about the associations between SDB and neurobehavioral problems has grown in recent years, increasing numbers of children come to medical attention, at least in part, because of parental concern about specific cognitive issues, disruptive behavior, or poor performance in school. Substantial existing literature on childhood SDB has documented neurobehavioral co-morbidities in pediatric SDB, and many clinicians, as well as some research studies [15], have targeted children who perform poorly in school as a high-risk group for occult SDB. This focus is understandable, but it also may raise the risk that high-performing, higher-IQ children will not have their underlying SDB recognized and treated as readily as other children. The most important suggestion in the current study of SDB -- possibly the first to focus on higher-IQ performing children, specifically -- is that such children, overall, seem as likely as other children to show improvement in parents' ratings of their children's cognitive skills, internalizing and externalizing symptoms, and hyperactive behaviors after adenotonsillectomy. These findings suggest that snoring, labored breathing, and other symptoms of SDB should be taken as seriously, and addressed as readily, in a bright, high-performing child as in a child with obvious cognitive and functional impairment.

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Table 1
Clinical and demographic characteristics (mean $\pm$ SD or n (%)) among all subjects and three IQ groups

Variables	All subjects (n=147)	Low IQ (IQ<90; n=28)	Average IQ (90 IQ<110; n=81)	High IQ (IQ 110; n=38)	p-value
Continuous variables					
Age, years	7.2 $\pm$ 2.5	7.6 $\pm$ 2.1	7.4 $\pm$ 2.7	6.6 $\pm$ 2.4	0.194
IQ	100.7 $\pm$ 14.9	81.0 $\pm$ 7.7	98.7 $\pm$ 6.3	119.5 $\pm$ 8.9	<0.001 ^{a,b,c}
Grade, years	1.5 $\pm$ 2.4	1.5 $\pm$ 2.2	1.7 $\pm$ 2.5	1.0 $\pm$ 2.4	0.309
Follow up duration (weeks)	31.2 $\pm$ 4.0	32.0 $\pm$ 3.7	31.2 $\pm$ 4.1	30.6 $\pm$ 4.1	0.390
Socioeconomic status [*]	2.6 $\pm$ 1.0	3.4 $\pm$ 1.0	2.6 $\pm$ 0.9	2.0 $\pm$ 0.6	<0.001 ^{a,b,c}
Body mass index (z-score)	0.6 $\pm$ 1.3	0.7 $\pm$ 1.4	0.8 $\pm$ 1.2	0.1 $\pm$ 1.3	0.024 ^{b,c}
RDI at baseline, events/hour	7.5 $\pm$ 10.0	12.0 $\pm$ 17.2	5.9 $\pm$ 7.0	7.7 $\pm$ 7.3	0.019 ^a
RDI at follow-up, events/hour	2.1 $\pm$ 1.8	1.9 $\pm$ 1.8	2.0 $\pm$ 1.8	2.2 $\pm$ 2.0	0.87
Minimum O ₂ saturation at baseline, %	90.1 $\pm$ 5.8	87.6 $\pm$ 8.7	91.0 $\pm$ 4.7	90.2 $\pm$ 4.6	0.023 ^a
Minimum O ₂ saturation at follow-up, %	92.2 $\pm$ 3.8	91.9 $\pm$ 2.9	92.4 $\pm$ 3.6	92.0 $\pm$ 4.8	0.79
Dichotomous variables					
Gender (male)	82 (55.8%)	17 (60.7%)	43 (53.1%)	22 (57.9%)	0.747
Race (white)	112 (76.2%)	16 (57.1%)	65 (80.2%)	31 (81.6%)	0.033 ^{a,b}

IQ, intelligence quotient; RDI, respiratory disturbance index

^{*} As distinguished by 5 Hollingshead categories (1, 2, 3, 4, 5, with 1 indicating highest socioeconomic status)

One way ANOVA test was done for continuous variables and Chi-square test for dichotomous variables.

^a p < 0.05 low vs. average IQ group;

^b p < 0.05 low vs. high IQ group;

^c p < 0.05 average vs. high IQ group.

Table 2

Changes in four domains of Conners' Parent Rating Scale in each IQ groups

Variables	Low IQ group (n=24)			Mid IQ group (n=71)			High IQ group (n=37)		
	Pre-AT	Post-AT	Change	Pre-AT	Post-AT	Change	Pre-AT	Post-AT	Change
Internalizing scales	49.4 ± 6.6	48.5 ± 7.5	-0.9 ± 6.3	49.9 ± 6.8	48.2 ± 6.8	-1.6 ± 6.9	48.5 ± 5.9	47.1 ± 6.9	-1.5 ± 4.0
Externalizing scales	51.9 ± 10.8	48.9 ± 8.3	-3.0 ± 11.0	52.1 ± 9.5	48.9 ± 7.1	-3.2 ± 7.5	49.9 ± 7.9	47.7 ± 7.8	-2.2 ± 5.8
Hyperactivity scales	55.8 ± 11.9	52.9 ± 10.1	-2.8 ± 8.5	57.2 ± 13.0	54.6 ± 12.9	-2.7 ± 9.7	54.8 ± 11.7	51.9 ± 12.1	-2.8 ± 7.1
Cognitive scale	53.9 ± 13.4	53.3 ± 11.2	-0.5 ± 7.4	57.1 ± 12.0	53.6 ± 11.3	-3.8 ± 10.2	54.5 ± 12.6	50.8 ± 10.6	-3.7 ± 8.6

IQ, intelligence quotient; AT, adenotonsillectomy

Table 3

Results of mixed model repeated measures analysis for IQ group

Conners' Parent Rating Scale	IQ group			Time			IQ group X time		
	DF	F	p-value	DF	F	p-value	DF	F	p-value
Internalizing domain	2	0.32	0.724	1	6.48	0.012	2	0.03	0.967
Externalizing domain	2	0.71	0.492	1	18.49	<0.001	2	0.40	0.671
Hyperactivity domain	2	0.46	0.634	1	15.03	<0.001	2	0.17	0.840
Cognitive domain	2	0.58	0.559	1	10.09	0.002	2	0.66	0.519

IQ, intelligence quotient; DF, degree of freedom