Improved Behavior and Sleep After Adenotonsillectomy in Children With Sleep-Disordered Breathing

Long-term Follow-up

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Objective: To determine whether previously published changes are maintained over time in children after adenotonsillectomy for sleep-disordered breathing using the validated Pediatric Sleep Questionnaire (PSQ) and the Conners Parent Rating Scale-Revised: Short Form (CPRS-R:S).

Design: Prospective, nonrandomized interventional study.

Setting: Ambulatory surgery center affiliated with an academic medical center.

Patients: Long-term follow-up data were available (ranging from 2.4 to 3.6 years after adenotonsillectomy) for 44 of the 71 patients who completed our initial study comparing PSQ and CPRS-R:S data before and 6 months after surgery.

Interventions: Parents completed the PSQ and CPRS-R:S at least 2 years after surgery.

Main Outcome Measures: Follow-up PSQ data and long-term changes in age- and sex-adjusted T scores for all 4 CPRS-R:S behavior categories (oppositional behavior, cognitive problems or inattention, hyperactivity, and the attention-deficit/hyperactivity disorder [ADHD] index) were determined for each patient. Linear mixed models were used to analyze the data.

Results: Globally, across time, most variables remained below baseline levels ($P < .05$). There was a significant increase in PSQ scores during follow-up, but over this period they did not reach baseline levels. Comparing short-term with long-term follow-up, the Conners scores in all behavioral categories did not increase significantly (ADHD index, $P = .61$; cognitive problems or inattention, $P = .02$; hyperactivity, $P < .001$; and oppositional behavior, $P < .001$). The ADHD index at long-term follow-up was not different from that at baseline, a finding that might be attributable to the high degree of variability in this measure.

Conclusions: Improvements in sleep experienced by children after adenotonsillectomy for sleep-disordered breathing were not as great 2.5 years after surgery as they were 6 months after surgery but were still significant compared with baseline levels. Improvements in behavior were maintained in all categories of the Conners scores except for the ADHD index.

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SINCE THE PUBLICATION OF OUR previous report demonstrating improvements in both sleep and behavior at 6 months after adenotonsillectomy for children with sleep-disordered breathing (SDB),[1] there have been several articles that continue to support the impact of SDB on neurocognitive development, behavior, and quality of life.[1-5] Specifically, attention-deficit/hyperactivity disorder (ADHD), hyperactivity, and behavior have been shown to improve at 6 or 12 months after adenotonsillectomy in correlation with improved postoperative polysomnography (PSG) parameters regardless of which instruments were used to evaluate behavior.[2-5] In fact, the 22-item Sleep-Related Breathing Disorder (SRBD) subscale score of the Pediatric Sleep Questionnaire (PSQ) has been shown to predict obstructive sleep apnea (OSA)-related neurobehavioral morbidity and its response to adenotonsillectomy as well or better than PSG.[2]

In our previous study, we found a statistically significant improvement in sleep after adenotonsillectomy as measured by a reduction in the PSQ scores ($P < .001$). We also reported a statistically significant reduction in the mean T scores for all 4 of the Conners Parent Rating Scale-Revised: Short Form (CPRS-R:S) categories: ADHD index, cognitive problems or

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inattention, hyperactivity, and oppositional behavior. Furthermore, we found that the greater the preoperative T score, the greater the reduction in the T score after adenotonsillectomy when patients were stratified into groups based on the severity of T scores. Based on our previous study, we demonstrated the usefulness of the PSQ as a tool for evaluating both sleep and behavior, as we calculated not only the 22-item SRBD subscale score but also the PSQm6 score (the SRBD minus the 6 behavioral questions, leaving 16 nonbehavioral items). The present study prospectively analyzed the same group of patients to see whether the improvements in sleep and behavior were maintained over time and to evaluate changes in sleep and behavior 2.5 years after surgery.

METHODS

This study received approval from the institutional review board of the University of Kansas Hospital, Kansas City. In our initial investigation, 117 consecutive children who were clinically diagnosed as having SDB were enrolled for evaluation. Seventy-one patients had complete follow-up data at 6 months after surgery, and they were all invited to participate in this follow-up study to evaluate whether improvements in sleep and behavior after adenotonsillectomy were maintained over time. We chose to use the same 2 instruments to measure changes in sleep and behavior, the PSQ and the CPRS-R:S, respectively. Specifically, the 22-item SRBD subscale score of the PSQ was used in data analysis just as in our previous study because it has been validated and found to have the strongest association with SRBD diagnosis. Caregivers of these patients had completed the CPRS-RS and PSQ questionnaires before and 6 months after adenotonsillectomy and were asked to complete the same 2 questionnaires 2.5 years after surgery.

THE CPRS-R:S AND THE PSQ

The CPRS-R:S, which is typically used in treatment studies to measure change in symptoms, is a 27-item form in which the respondents indicate the frequency of behaviors observed in the patients in the previous month.[6,7] The CPRS-R:S profile forms automatically transform raw scores into T scores, which can easily be converted to percentile ranks. T scores are standardized scores for each scale and have the same mean (50) and standard deviation (SD) (10). The CPRS-R:S forms have age- and sex-normed T scores, and their validity and reliability as well as their long-term stability have all been tested and published. Higher T scores represent worse behavior in each specific CPRS-R:S category. Boys have higher scores than girls.

Changes in age-appropriate T scores for all 4 behavior categories (oppositional, cognitive/inattention, hyperactivity, and ADHD index) comparing scores before and at 6 months after adenotonsillectomy were previously published.[1] The changes in mean T scores for all respondents from before surgery to the current long-term follow-up periods were determined for each behavior category. As previously demonstrated, a specific 22-item SRBD subscale was used for scoring the PSQ, as these were the items found to have the strongest association with the SRBD diagnosis.[2] Each item is scored 1 for yes and 0 for no, and "don't know" and missing data are treated as missing. The responses are totaled and then divided by the number of questions for which a response is given, and then the score is obtained on a scale of 0 to 1. Scores approaching 1 represent the greatest severity in sleep disturbance. A score higher than 0.33 suggests a high risk for SDB with reasonable sensitivity and specificity.[2] To see how the PSQ relates to the CPRS-R:S, we calculated the SRBD subscale as described above but left out the last 6 behavior items in the PSQ because they are also found in the CPRS-R:S. The 22-item PSQ subscale without the 6 behavioral questions is the PSQm6 (PSQ minus 6 behavioral questions, leaving 16 nonbehavioral items). Whenever the PSQ score is reported, we are referring to the 22-item SRBD subscale score.

STATISTICAL ANALYSIS

Categorical demographic variables are summarized by frequencies and percentages, and quantitative demographic variables are summarized by means and SDs. We used linear mixed models to assess the longitudinal relative change from baseline for outcome measures, as we were working with repeated-measures data in which there were different numbers of repeated measurements and different intervals for different cases. At each time point, we also used a paired *t* test to determine whether the relative change differed from the baseline.

RESULTS

Of the 117 patients enrolled in the original study, 71 completed the 6-month follow-up after adenotonsillectomy.[1] For the purposes of this study, these 71 patients and their caregivers were contacted to participate in this long-term follow-up. The SRBD subscale scores were available for 44 patients, and the CPRS-RS scores were available for 43 patients at the 2.5-year follow-up visit, a 62% response rate. The median follow-up in our first study was 0.49 years, while the median follow-up period for this current cohort was 2.5 years (range, 2.4-3.6 years). There were no differences found between the patients who completed the 2.5 years of follow-up and those who did not complete the 2.5 years of follow-up with respect to age, sex, and race. Demographics of the 71 patients who were the focus of this study are shown below:

Variable	Value
Age, mean (SD), y	6.4 (3.1)
Sex, No. (%)	
Male	36 (49)
Female	36 (51)
Race, No. (%)	
White	57 (80)
Other	14 (20)

The mean (SD) age of the patients who were included in the long term follow-up was 6.2 (2.8) years. There was a slight male to female predominance (57% vs 49%), and most of the patients were white. The mean (SD) PSQ score for this group was 0.21 (0.22), and the mean (SD) PSQm6 score for the group was 0.33 (0.35). At the 2.5-year follow-up, there was a statistically significant reduction of 58% (SD, 0.45) in the mean score of the PSQ relative to the baseline scores ($P < .001$). There was also a statistically significant reduction of 38% (SD, 0.66) in the mean score of the PSQm6 relative to the baseline scores ($P < .001$). For each year after surgery, the PSQ and PSQm6 scores increased by 7% and 17%, respectively. While this increase in PSQ and PSQm6 scores over time was statistically significant, the scores were both well below baseline scores, and the overall reduction in scores compared with the preoperative scores remained statistically significant ($P < .001$).

Table 1. Summary of Relative Change From Baseline for All Values at 6 Months and 2.5 Years of Follow-up

Variable	No. of Patients	Mean (SD)	*P* Value
6 Months after surgery			
PSQ (22-item SRBD subscale)	71	−0.75 (0.25)	<.001
PSQm6	71	−0.79 (0.24)	<.001
ADHD index	70	−0.10 (0.32)	.02
Cognitive problems/inattention	69	−0.10 (0.19)	<.001
Hyperactivity	70	−0.11 (0.18)	<.001
Oppositional behavior	70	−0.10 (0.16)	<.001
2.5 Years after surgery			
PSQ (22-item SRBD subscale)	44	−0.58 (0.45)	<.001
PSQm6	44	−0.38 (0.66)	<.001
ADHD index	43	−0.04 (0.52)	.61
Cognitive problems/inattention	43	−0.08 (0.21)	.02
Hyperactivity	43	−0.17 (0.17)	<.001
Oppositional behavior	43	−0.12 (0.20)	<.001

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; PSQ, Pediatric Sleep Questionnaire; PSQm6, PSQ subscale minus 6 behavioral questions; SRBD, Sleep-Related Breathing Disorder.

Table 2. Assessing the Effect of Time Using Linear Mixed Models[a]

Variable	Estimate (SE)	*P* Value
PSQ	0.068 (0.026)	.01
PSQm6	0.166 (0.037)	.001
ADHD index	0.020 (0.015)	.18
Cognitive problems/inattention	0.010 (0.013)	.47
Hyperactivity	−0.022 (0.010)	.02
Oppositional behavior	−0.007 (0.012)	.56

See Table 2 for expansions of abbreviations.
[a] Separate models were run for each variable. Estimate refers to the slope coefficient corresponding to time; SE is the standard error of the estimate; and the *P* value is the significance level for testing whether the slope is equal to 0.

Table 1 shows the summary of relative change from baseline for all values at the 6-month follow-up and at the 2.5-year follow-up. Relative to the baseline scores 2.5 years earlier, before adenotonsillectomy, there was a mean reduction of 8% (SD, 0.21) in the mean T score of cognitive problems or inattention ($P<.02$), which demonstrates a less than 1% increase per year. For the hyperactivity category, there was a reduction of 17% (SD, 0.17) in the mean T score relative to the baseline score ($P<.001$), and the hyperactivity T score actually continued to decrease by 2% per year, which was statistically significant ($P<.01$). The mean T scores for oppositional behavior demonstrated a reduction of 12% (SD, 0.20) ($P<.001$) compared with the baseline score, which was essentially stable and unchanged and was still found to have decreased by less than 1% per year. Finally, for the ADHD index, there was a reduction of 4% (SD, 0.52) in the mean T score ($P=.61$) compared with baseline, which reflects a 2% increase per year (not statistically significant, $P=.17$). **Table 2** assesses the effect of time on each variable using mixed linear models and shows whether there was a significant change from the baseline over time. When the information from Tables 1 and 2 is compared, it is obvious that the changes in PSQ and PSQm6 scores were significantly different from baseline scores at 6 months and 2.5 years, but there was an increase from 6 months to 2.5 years; the change in the ADHD index was significantly different at 6 months but this difference was not maintained at 2.5 years ($P=.61$); the change in cognitive problems/inattention was significantly below baseline and was maintained over time ($P=.02$); the change in hyperactivity was statistically significant compared with baseline, and this difference continued to increase over time ($P<.001$); and change in oppositional behavior was significantly below baseline and was maintained over time ($P<.001$).

In our first article describing the 71 patients who completed the 6 months of follow-up, we were able to stratify patients into 4 groups based on their preoperative T scores to demonstrate that the greater the preoperative T score, the greater the reduction in the postoperative T score. However, because there were only 44 patients who completed the 2.5-year follow-up, there were not enough patients to stratify them into separate groups and still be able to maintain power for statistical analysis.

COMMENT

The starting cohort for this long-term follow-up study comprised 71 patients who underwent adenotonsillectomy for clinically diagnosed SDB and who completed the initial 6 months of follow-up. Our results demonstrate that improvements in sleep and behavior as measured by the PSQ and the CPRS-R:S lessened over time, but the scores were still below baseline levels. In our first article, we addressed the challenge of the loss of some patients at the 6-month follow-up after surgery, which left 71 of 117 enrolled patients to complete the first study. Two and half more years after the initial adenotonsillectomy, only 44 of the 71 patients completed our long-term follow-up. There were no differences with respect to age, sex, and race between the patients who did complete and those who did not complete both the 6-month and the 2.5-year follow-up, and there were no differences between the demographics of the 71 patients who completed the first follow-up and those of the 44 patients who completed the long-term follow-up. We regret not including body mass index as a study parameter as it may be an important predictive variable that may influence the long-term outcome in cases of SDB.

We chose the linear mixed model for data analysis because it allowed us to use all of our data and resulted in more accurate analysis. Linear mixed models are frequently used to analyze repeated-measures data because they are more flexible to modeling the within-subject correlation. The linear mixed model is a further generalization of the general linear model that can better support analysis of a continuous dependent for (1) random effects, whereby the set of values of a categorical predictor variable are seen not as the complete set but rather as a random sample of all values; (2) hierarchical effects, whereby predictor variables are measured at more than 1 level; and (3) repeated measures, whereby observations are correlated rather than independent, such as before-after studies and time series data.

We chose a consecutive convenience sample for patients who had a clinical history of SDB and assessed their sleep using the SRBD subscale of the PSQ. This subscale has been shown to have good sensitivity and specificity for predicting OSA measured by PSG.[2] Recently, Chervin et al[3] demonstrated that compared with several standard polysomnographic measures of OSA, the baseline SRBD subscale may predict OSA-related neurobehavioral morbidity and its response to adenotonsillectomy as well or better than PSG.

The mean age of our long-term follow-up group was 6.2 years, similar to the mean age of 6.4 years of the group that we reported on 2 years earlier at 6 months after adenotonsillectomy. The mean age of this group did not increase over time, which reflects the bias in the long-term follow-up group, including more children who were younger at the time of their adenotonsillectomy, with fewer of the older patients included in this long-term follow-up group. This finding was unexpected, as all 71 patients who completed the first follow-up at 6 months after surgery were invited for participation regardless of age. Ideally, had all 71 patients completed the long-term follow-up, the mean age would have increased to reflect the patients' actually aging 2.5 years.

Table 1 is a descriptive and summary table of each time point compared with baseline, and Table 2 assesses the effect of time to determine whether the effects seen at 6 months differ from those at 2.5 years after surgery. At 2.5 years after adenotonsillectomy, the mean PSQ score for our current group of 44 patients was 0.21, which is still well below 0.33 and which suggests that if the PSG were performed the results would likely be negative for SDB because only patients with PSQ scores greater than 0.33 are considered at risk for positive sleep study findings.[3] The mean PSQm6 score for this group was 0.33, which means that the answers to the 6 behavioral questions, when included, brought the average of the PSQ score down. This difference may be interpreted by saying that over time there is an increase in the symptoms that are suggestive of increasing SDB as reported by parents when behavior scores are not included or that improvement in behavior is much greater than the improvement in the sleep symptoms that are related to SDB. The PSQ and PSQm6 scores longitudinally increased over time but still stayed below baseline levels, so while improvements in sleep deteriorated over time and were not as great at 2.5 years after surgery as they were at 6 months, the relative change at 2.5 years compared with baseline was still statistically significant ($P < .001$ for both PSQ and PSQm6).

Hyperactivity scores continued to decrease compared with baseline scores, and since the CPRS-R:S has age- and sex-adjusted T scores, it is clear that the decrease in hyperactivity is not just a reflection of children behaving with less hyperactivity simply because of increased age. In pharmacotherapy studies, it has been shown that the effect of drugs on a child's behavior might also have an effect on the reaction of significant others.[8] This effect has been illustrated in studies of hyperactive children in which the drug increased the children's compliance and cooperation, which in turn increased the parents' positive interactions with the children. The positive interactions of the parents further decreased the children's noncompliance, tantrums, and aggression and improved their attention to tasks.[9-11] Positive interactions with parents may account for the continued decrease in the measure of hyperactivity, which initially improved after adenotonsillectomy. Chervin et al[12] previously used PSQ and CPRS-R:S together in a 4-year prospective cohort study and demonstrated that the symptoms of SDB actually precede the development of hyperactivity.

Follow-up of even longer than 2.5 years may be necessary to investigate how hyperactivity scores will change over time relative to the change in sleep as reported by the SRBD subscale score. The ADHD index did not increase significantly, but at 2.5 years after surgery, the score was no longer below baseline. Because of the high variance in scores (mean [SD], 0.04 [0.52]), we cannot confirm that improvement in this category was maintained over time (Table 1). Cognitive problems or inattention and oppositional behavior did not change over time and were continuously below baseline levels during the study period.

In a prospective cohort study of children aged 5 to 12 years, Dillon et al[13] demonstrated that adenotonsillectomy may be associated with reduced morbidity of inattention and disruptive behavior disorders, even among patients who are lacking PSG evidence of OSA. Another study showed that among children diagnosed as having ADHD with PSG-confirmed mild OSA, those who underwent adenotonsillectomy demonstrated greater improvement than the medically treated group based on an apnea-hypopnea index, an ADHD rating scale, a child behavior checklist, a test of variable attention, and a quality-of-life questionnaire (OSA-18).[14] Regarding oppositional behavior and cognitive problems or inattention, there was a less than 1% increase per year in the T score in this longitudinal model, so the reduction in postoperative T scores reflecting improvement in behavior was maintained over time. The increase of only 2% per year in the T scores of the ADHD index was not found to be statistically significant ($P = .61$).

Li et al[15] evaluated a group of children before and 6 months after adenotonsillectomy and found significant improvement in behavior and attention. They also found that ADHD scores were normalized in 78% of children but that improvements in the test of variable attention scores did not correlate with an improved apnea-hypopnea index on the PSG, once again demonstrating that the goal for evaluating functional improvement in children with SDB must address more than simple normalization of the PSG measure. Chervin et al[16] found behavioral improvement in children 1 year after adenotonsillectomy when compared with controls using the Conners ratings questionnaire and memory scale. They also found that PSG measures at baseline or improvement in PSQ measures after surgery were poor predictors regarding which children showed either baseline abnormalities or postoperative improvement in behavior or neurocognitive function. If the positive impact of the alleviation of SDB on neurocognitive functioning and behavior is not adequately predicted based on PSG measures, then that may be an important point for future study.

Our longitudinal study demonstrates that improvements in sleep and behavior may not be exactly maintained over time, but at 2.5 years after the surgical intervention, all parameters reported in this study except the ADHD index remained below baseline values. Although speculative and based on extrapolation, this longitudinal model shows that even if the SRBD subscale scores increase by 7% per year for many consecutive years, which is a statistically significant increase compared with baseline values, it would take 9 or 10 years before the values could climb back to baseline values, if indeed a return to baseline values were likely. This longitudinal observational study supports an association between adenotonsillectomy and changes in sleep and behavior, but because it is not randomized or controlled as an intervention trial, the relationship cannot be proved. The strength of this study is that although the evaluation tools we chose were subjectively reported by parents and caregivers, at an additional 2 years after the surgery caregivers should not remember their responses from the initial surveys and should be rating their children based on their current status, thus offering a relatively unbiased view compared with earlier responses.

Although our patients did not undergo PSG, we believe that the findings of this study support the need for more sensitive measures of disruption of sleep architecture other than PSG and that such measures are critical to better correlate with functional and behavioral outcomes after adenotonsillectomy for SDB. Several studies have demonstrated improvement in behavior, cognition, and quality of life after adenotonsillectomy for SDB using validated instruments, but because of the absence of randomized trial data, the definitive evidence for the efficacy of adenotonsillectomy for SDB has not yet been fully demonstrated.

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Author Contributions: Dr Wei had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Wei, Mayo, Reese, and Weatherly. *Acquisition of data:* Wei and Bond. *Analysis and interpretation of data:* Mayo, Smith, Reese, and Weatherly. *Drafting of the manuscript:* Wei, Mayo, and Reese. *Critical revision of the manuscript for important intellectual content:* Wei, Bond, Mayo, Smith, Reese, and Weatherly. *Statistical analysis:* Mayo and Smith. *Administrative, technical, and material support:* Wei, Bond, Reese, and Weatherly. *Study supervision:* Weatherly. *Data management:* Smith.
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