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Predictors of Perioperative Complications in Higher Risk Children after Adenotonsillectomy for Obstructive Sleep Apnea: A Prospective Study

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Abstract

Objective—Retrospective studies have limitations in predicting perioperative risk following adenotonsillectomy in children with obstructive sleep apnea syndrome (OSAS). Few prospective studies exist. We hypothesized that demographic and polysomnographic (PSG) variables would predict respiratory and general perioperative complications.

Study Design—Prospective, observational cohort study.

Setting—Pediatric tertiary center.

Subjects and Methods—Consecutive children undergoing adenotonsillectomy for OSAS within 12 months of PSG were evaluated for complications occurring within 2 weeks of surgery.

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Disclosures

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Results—There were 329 subjects, with 27% <3 years old, 24% obese, 16% preterm, and 29% with comorbidities. In this higher risk population, 28% had respiratory complications (major and/or minor), and 33% had nonrespiratory complications. Significant associations were found between PSG parameters and respiratory complications as follows: apnea hypopnea index (rank-biserial correlation coefficient [*r*] = 0.174, *P* = .017), SpO_2 nadir (*r* = –0.332, *P* <.0005), sleep time with SpO_2 <90% (*r* = 0.298, *P* <.0005), peak end-tidal CO_2 (*r* = 0.354, *P* <.0005), and sleep time with end-tidal CO_2 >50 mm Hg (*r* = 0.199, *P* = .006). Associations were also found between respiratory complications and age <3 years (*r* = –0.174, *P* = .003) or black race (*r* = 0.123, *P* = .039). No significant associations existed between PSG parameters and nonrespiratory complications. A model using age <3 years, SpO_2 nadir, and peak CO_2 predicted respiratory complications better than the American Academy of Pediatrics or American Academy of Otolaryngology—Head and Neck Surgery Foundation guidelines but was imperfect (area under the curve = 0.72).

Conclusion—Thus, PSG predicted perioperative respiratory, but not nonrespiratory, complications in children with OSAS. Age <3 years or black race are high-risk factors. Present guidelines have limitations in determining the need for postoperative admission.

Keywords

adenotonsillectomy; obstructive sleep apnea; polysomnography

Obstructive sleep apnea syndrome (OSAS) is a highly prevalent condition, affecting 1% to 4% of children.[1] The most common treatment is adenotonsillectomy.[2] Surgery can be associated with complications. Known high-risk groups for perioperative complications include children <3 years of age and those with obesity, comorbidities, or severe OSAS on polysomnography (PSG).[2-5]

Potential complications of adenotonsillectomy include respiratory complications such as hypoxemia, hypercapnia, and postoperative pulmonary edema, which may require interventions such as intubation; anesthetic complications; and nonrespiratory complications such as pain, poor oral intake, and airway hemorrhaging.[6-14] Most children undergo adenotonsillectomy as outpatients, but those at an increased risk are usually admitted to the hospital electively, with much variation in clinical practice.[15,16] In 2006, the American Society of Anesthesiologists published a practice guideline for the perioperative management of patients with OSAS that noted pediatric-related risk factors, including obesity and age <3 years.[17] In 2011, the American Academy of Otolaryngology— Head and Neck Surgery Foundation (AAO-HNSF) published guidelines recommending children with OSAS <3 years of age or those with severe OSAS (apnea hypopnea index [AHI] ≥10/h and/or oxygen saturation [SpO_2] nadir <80% on PSG) or other comorbidities be admitted postoperatively.[18] In 2012, the American Academy of Pediatrics (AAP) also published guidelines recommending postoperative admission for children with OSAS who are age <3 years, are obese, or have serious comorbidities or severe OSAS (AHI >24/h, SpO_2 nadir <80%, or peak PCO_2≥60 mm Hg).[2] Thus, clinical guidelines provide conflicting advice regarding OSAS severity scores and the need for electively planned admission. This has both social and economic implications.

One reason for contradictions in practice guidelines is that recommendations have typically been based on data from retrospective studies or on expert consensus.[2,18] Few prospective studies have evaluated the relationship between PSG abnormalities and perioperative complications, and those that have been prospective have had limited sample sizes.[19] Further, the focus has been on relatively healthy children. Few address higher risk children frequently seen at academic pediatric medical centers. We therefore performed a prospective study evaluating perioperative complications in children with PSG-proven OSAS, hypothesizing that PSG variables would predict respiratory complications in the perioperative period, including more clinically important "major" complications that would require an intervention beyond the postanesthesia care unit (PACU) period. Moreover, we hypothesized that demographic variables (age <3 years, race, and presence of obesity or other comorbidities) would also predict general postoperative complications (bleeding, dehydration, and pain). We also aimed to evaluate the validity of current PSG-based admission guidelines and propose risk-predicting threshold values for PSG parameters that could be used to help determine which children are more likely to benefit from overnight admission postoperatively.

Materials and Methods

The study was conducted with approval from The Children's Hospital of Philadelphia (CHOP) institutional review board. Informed consent was obtained from parents/guardians and assent obtained for children >7 years of age.

Subjects were eligible if they were <18 years of age, were undergoing adenotonsillectomy for OSAS, had undergone PSG at CHOP 12 months prior to adenotonsillectomy showing an AHI ≥1.5 per hour,[20-23] and had surgery at the main campus of CHOP. The 12-month limit was chosen as an arbitrary cutoff, during which time major changes in growth and development were unlikely to occur. At CHOP, PSG findings are obtained to evaluate both high-risk children and to diagnose OSAS in those whose primary symptom may only be snoring, so the study group represented a broad range of OSAS severity. Patients with normal PSG results were excluded from this study. Of note, CHOP performs surgery at the main campus and satellite centers. Children who are <4 years old, are obese, and have significant comorbidities or severe OSAS are scheduled to undergo surgery only at the main campus. Thus, this cohort oversampled high-risk children but also included patients who were scheduled for day surgery and those who were admitted due to surgeon preference, even though they were eligible for day surgery. Patients were excluded if caregivers declined inclusion in the study or could not understand English sufficiently to provide informed consent, if patients underwent other simultaneous surgical procedures (except for minor ear surgery), or if they had planned postoperative hospitalization for comorbid conditions unrelated to surgery.

The study was a prospective, observational cohort study that was performed from May 2012 to May 2013. Consecutive families were approached for consent in the preoperative area on the day of surgery. Medical records were reviewed for history, physical examination, and PSG variables. Subjects were then followed prospectively from the time that they entered the operating room until discharge, with a follow-up telephone call 2 weeks following

discharge. All PSG evaluations were performed and scored according to the American Academy of Sleep Medicine pediatric guidelines by pediatric PSG sleep technologists and interpreted by sleep board-certified pediatricians.[24]

Intraoperative complications were recorded at the time of surgery by the anesthesiologist using a standardized data collection tool. After surgery, a research team member observed patients in the PACU, and any interventions were recorded. As per the clinical protocol, patients with severe OSAS (usually with an AHI >10-15/h or SpO_2 nadir <80%), obesity, or serious medical comorbidities were electively admitted. All children <3 years and some <4 years of age were admitted, depending on surgeon preference. Patients <1 year of age or those with severe OSAS and/or comorbid conditions were admitted electively to the intensive care unit (ICU). If patients were admitted, a research team member reviewed their charts and interviewed their health care providers daily until discharge. Finally, caregivers were telephoned 2 weeks after surgery to capture postdischarge complications. At all points of contact, data were collected and entered using standardized case report forms. Parameters that were tracked included hypoxemia (SpO_2 <90% requiring intervention); hypercapnia (PCO_2 >50 mm Hg); laryngospasm; bronchospasm; interventions such as supplemental oxygen, nasopharyngeal airway use, continuous positive airway pressure (CPAP), bilevel positive airway pressure, prolonged postoperative endotracheal intubation, or reintubation requiring admission to the pediatric ICU; airway bleeding; poor oral intake requiring continued intravenous fluid administration; poorly controlled nausea and vomiting requiring antiemetic medication; dehydration; fever; poorly controlled pain requiring additional medications (parenteral or increased dose of oral opioids); and planned/unplanned ICU or inpatient unit admission. Minor respiratory complications were categorized as those occurring intraoperatively or anytime during the postoperative period, which either resolved spontaneously or could be reversed with a minor intervention such as an oxygen mask and which did not require the child to be admitted overnight. Major complications were defined as those requiring an intervention beyond the PACU period to support the patient's airway (intubation or nasopharyngeal airway) or oxygen to maintain the blood oxygenation level >92% that was applied throughout the first postoperative night or longer. The primary analysis was performed to determine the incidence of total respiratory complications, and a secondary analysis was performed to determine the incidence of “major” complications (clinically important outcomes that justified an overnight admission). During the study period, standard clinical practice for pain control included the use of a combination of acetaminophen and an opioid (either hydrocodone [0.135 mg/kg/dose every 4-6 hours] or oxycodone [0.05-0.07 mg/kg/dose every 4-6 hours]) that was titrated as the patient clinically improved. Several patients received ibuprofen to control “breakthrough pain” over the last 3 months of the study due to changing clinical practice.

Statistical Analysis

Statistical analyses were conducted in Stata 13.0 (Stata Corp LP, College Station, Texas) and SPSS (IBM, Armonk, New York), with 2-sided tests and a P value <.05 as the criterion for statistical significance. Results are shown as the mean ± standard deviation for normally distributed data and the median (minimum-maximum) for skewed variables. Two-sample t tests or Mann-Whitney tests were used to compare differences between subgroups (eg, obese

vs nonobese) for continuous outcomes. When more than 2 subgroups were involved, analyses of variance (ANOVAs) or Kruskal-Wallis tests were used. The Fisher exact test was used to compare proportions between 2 groups. Rank-biserial correlations were obtained to assess the association between PSG parameters and postoperative complications.

Logistic regression models were constructed to explore the relationship between PSG variables and postoperative complications and also to examine overall predictive models of postoperative complications. A stepwise method was used to select independent variables from a pool of variables that included demographic (age, race, and sex) and anthropometric (eg, body mass index [BMI] Z score) variables, PSG parameters (AHI, peak end-tidal CO_2, and SpO_2 nadir), and clinical variables (eg, presence of pre-existing conditions such as craniofacial syndromes and/or neuromuscular and pulmonary diseases). Based on univariate tests, variables with a P value ≤.10 were included in the pool of potential predictors. In addition, to compare the predictive ability of models based on current practice guidelines, models were constructed that included 1 covariate that indicated whether the patient satisfied the AAP or AAO-HNSF guidelines for admission.

Goodness of fit of the logistic models was assessed using the Hosmer-Lemeshow test for adequate fit. In addition, receiver operating characteristic (ROC) analysis was used to assess the predictive ability of the logistic models. The ROC curves were constructed for the final multivariable logistic model for postoperative complications and for each univariable model based on satisfaction of the AAP or AAO-HNSF guidelines for admission. An area under the curve (AUC) value for an ROC curve that is close to 1 demonstrates better predictive ability of a model, while a value close to 0.50 indicates a model with poor performance.

Results

Study Group

Figure 1 shows the subject flow. There were 386 patients who met the eligibility criteria, of whom 329 (85%) agreed to participate. Postdischarge information was available from 316 of 329 (96%) subjects (**Figure 1**). There were 261 patients (79%) who were electively admitted, and 68 (21%) were discharged from the day surgery unit. Of those, 31 (11.9%) had no risk factors identified by either guideline, but 1 remained because of arrhythmia noted in the PACU. The rest of the patients remained in the hospital because some physicians preferred to admit all patients aged <4 years or because the family lived far away. The mean age was 5.3 ± 3.6 years. Moreover, 176 (53.5%) were male, 162 (49.3%) were white, 108 (32.8%) were black, and the remaining 59 (17.9%) were of other racial designations. Many subjects fell into categories considered to be high risk: 89 (27.1%) were <3 years of age, 78 (23.7%) were obese (BMI >95th percentile), and 95 (29%) had serious comorbidities (46 with neuromuscular disease, 19 with Down syndrome, 19 with congenital heart defects, 6 with craniofacial anomalies, 4 with chronic lung disease, and 1 with sickle cell disease). Also, 119 (36%) patients had asthma, 29 (12%) had failure to thrive (FTT) with height and/or weight <5th percentile, and 52 (15.8%) had a history of prematurity. Mean PSG indices were as follows: AHI, 19.5 ± 21.3 events per hour; arousal index, 21.3 ± 11.7 events per hour; SpO_2 nadir, 84.3% ± 7.5%; percentage of total sleep time with SpO_2

<90%, 2.3% ± 7%; peak end-tidal CO_2, 57.4 ± 7.4 mm Hg; and percentage of total sleep time with end-tidal CO_2 >50 mm Hg, 20.8% ± 26%.

Length of Stay

Figure 1 shows elective and unplanned admissions. The mean length of PACU stay for day surgery patients was 2.0 ± 0.6 hours. The mean length of stay for inpatients was 33.1 ± 21.4 hours: 31.8 ± 19.5 hours for planned inpatient admissions, 168.0 ± 0.0 hours for unplanned inpatient admissions, 36.0 ± 20.3 hours for planned ICU admissions, and 30.0 ± 12.0 hours for unplanned ICU admissions. Most patients admitted for >24 hours had nonrespiratory complications, primarily poor oral intake.

Respiratory Complications

In this high-risk population, 90 (27.4%) children had ≥1 adverse respiratory events or complications at some point in care (intraoperatively, in the PACU, or as an inpatient). There were 55 (16.7%) who had major respiratory complications requiring overnight admission. Further, 32.8% had nonrespiratory complications. Of the patients requiring an airway intervention, 20 (6.9%) had a nasopharyngeal airway, 1 underwent high-flow nasal cannula oxygen therapy, 5 had CPAP, 1 had bilevel positive airway pressure, and 2 underwent endotracheal intubations. Overall, 63 (19.1%) required supplemental oxygen while in the PACU to maintain oxygen saturation levels >92%. Of these children, 51 (81%) continued to require oxygen after transferring to the ward. Of the intubated children, one 5-year-old child remained intubated postoperatively due to upper airway edema (preoperative AHI, 22.7/h; end-tidal CO_2 peak, 65 mm Hg; SpO_2 nadir, 70%). Another child with a history of extreme prematurity was reintubated postoperatively due to pulmonary edema (preoperative AHI, 18.3/h; end-tidal CO_2 peak, 70 mm Hg; SpO_2 nadir, 78%). Both were extubated within 24 hours.

Other perioperative minor respiratory events were categorized according to when they occurred: (1) intraoperatively or (2) postoperatively in the PACU. All resolved with minor interventions or time and included the following: (a) laryngospasm: n = 5 (1.5%) and n = 4 (1.2%); (b) bronchospasm: n = 3 (0.9%) and n = 2 (0.6%); (c) hypoxemia (SpO_2 <90%): n = 32 (9.7%) and n = 48 (14.6%); and (d) hypercapnia (end-tidal CO_2 >50 mm Hg): n = 50 (15.2%) and n = 5 (1.5%), respectively. Patients who had major complications were more likely to have had intraoperative hypoxemia (n = 15/32, 46.9%) or hypercapnia (n = 14/50, 28%).

Nine patients developed upper respiratory infections either during admission (n = 5, 1.5%) or after hospital discharge (n = 4, 1.2%), requiring albuterol therapy and/or antibiotics. These postoperative events were not counted in our analysis, assuming that they occurred as a result of the infection rather than directly from surgery.

Nonrespiratory Complications

Table 1 shows the frequency of nonrespiratory complications categorized by timing of the occurrence.

Subgroup Analysis

Table 2 demonstrates the frequency of complications in subgroups. Children <3 years old and those with FTT (regardless of age) were more likely to have major respiratory complications justifying admission. Children of black race had a higher rate of overall respiratory complications, although this did not reach statistical significance for major complications. None of the high-risk groups had a higher incidence of nonrespiratory complications.

The more severe the OSAS, the more likely the patient was to have major and/or minor respiratory but not nonrespiratory complications (**Table 3** and **Figure 2**). There were 143 (43.5%) subjects who met AAP admission criteria, and 206 (62.6%) met AAO-HNSF admission recommendations. Logistic regressions were used to examine the predictive value of PSG parameters for the occurrence of complications. Neither AAO-HNSF nor AAP criteria, nor a model derived from our study, predicted nonrespiratory complications. There was a significant association between AAP criteria and total respiratory complications ($P = .005$), although with a low AUC as measured by ROC analysis, but not between AAO-HNSF criteria and total respiratory complications ($P = .129$) (**Table 4**). Using data from the current study, a model comprising age <3 years, SpO_2 nadir, and peak CO_2 predicted total respiratory complications better than either AAP or AAO-HNSF guidelines but was imperfect (AUC = 0.72) (**Figure 3**).

Discussion

This study confirmed that the incidence of perioperative complications during or after adenotonsillectomy is clinically significant in a diverse, high-risk group of children with PSG-proven OSAS. Significant associations existed between respiratory PSG parameters and total respiratory complications. These findings were replicated in a subanalysis of patients who had more clinically important major respiratory complications (requiring ongoing airway interventions or oxygen therapy after PACU discharge). Analysis of the current study revealed variables that identified patients who needed postoperative observation better than parameters described in currently available guidelines.[18,19] Although both AAP and AAO-HNSF guidelines have described severity cutoffs using AHI values to determine which patients should be admitted postoperatively, our study demonstrated that abnormalities in gas exchange were more helpful in defining severity thresholds based on the incidence of respiratory complications (**Figure 2**). Specifically, data showed that patients were more likely to have adverse respiratory events if the SpO_2 nadir was <80% and/or end-tidal CO_2 peak was >60 mm Hg on PSG. However, a clinically optimal predictive model that included other known demographic risk factors could not be determined. These study findings are important, as they demonstrate that PSG reliably provides information that can help clinicians prepare for potential adverse events related to postoperative respiratory recovery, but the decision to admit patients postoperatively for monitoring should also include physician clinical judgment based on the patient's other risk factors and social situations.

The literature and recent guidelines have been more consistent in their recommendations for postoperative overnight monitoring based on demographic risk factors rather than OSAS

severity scores.[2,3,5,10,13,14,18,19,25-29] Specifically, both AAP and AAO-HNSF guidelines agree that children should be admitted postoperatively if they have high-risk factors including age <3 years, obesity, and/or various comorbidities.[2,3,5,10,13,14,18] In the current study, only some demographic characteristics were found to be significantly associated with adverse major respiratory events (age <3 years and presence of FTT [regardless of age]), but we did not find this to be true for children who had a history of prematurity, other comorbidities, or obesity. Although black children were found to be at a higher risk for total adverse respiratory events such as laryngospasm, bronchospasm, or need for oxygen in the PACU, there was only a trend for them to have major respiratory complications. Black children have been shown to have a higher prevalence of OSAS and less improvement postoperatively than patients in other racial groups, which may relate to differences in the craniofacial structure, ventilatory drive, or exposure to allergens and/or environmental toxins.[30,31] Further prospective studies are needed to determine whether race should be an additional consideration for elective admission postoperatively.[32]

In the current study, the most common objectives for admission were to supply oxygen or to provide airway monitoring or intervention (nasopharyngeal/oral airway placement or less commonly CPAP or endotracheal intubation). Given the relatively high incidence of respiratory events in this cohort, we believe that overnight observation was warranted because an intervention was necessary in approximately one fifth (55/256) of admitted patients. Furthermore, several children who were initially normoxic in the PACU desaturated later during inpatient admission. Other studies have shown that desaturation may be delayed 5 to 14 hours postoperatively.[10,13,14] This may relate to alterations in the timing of sleep, especially rapid eye movement sleep, which is associated most with obstructive events and which occurs in the early morning hours.[33]

This study also sought to determine whether associations existed between PSG-proven OSAS and nonrespiratory complications. Studies suggest that children with OSAS have more postoperative sleepiness and may be particularly sensitive to postoperative opiate analgesia.[5,27,34,35] It is possible that poor oral intake may lead to dehydration with scabbing of the throat and an increased risk of bleeding. However, we found no significant association between PSG parameters and nonrespiratory complications, and the incidence of nonrespiratory complications was similar to those from other studies.[8,9,29]

Strengths of this article are that the data were collected prospectively from a large tertiary pediatric center, with a diverse group of children followed until discharge and in which most were contacted 2 weeks after to identify late complications that may have occurred elsewhere. Also, we were stringent in our definition of major and minor respiratory complications, which were analyzed both together and independently.

Limitations of this study relate mostly to generalizability, given the disproportionate number of high-risk children treated at a tertiary center. In this setting, PSG studies are performed both to determine the severity in high-risk children as well as to diagnose the presence of OSAS in otherwise healthy children who present with snoring and few other symptoms. As such, it is not clear if our analysis of major complications was underpowered. Another limitation is that our practice may differ from others, as opioid (as well as nonopioid)

medications are still used to control pain, which could increase the risk of postoperative respiratory depression.

In conclusion, this study has shown that age <3 years, black race, and preoperative PSG findings (particularly abnormal gas exchange) predicted total respiratory but not nonrespiratory perioperative complications in children with OSAS. Preoperative SpO_2 nadir <80% or peak CO_2 >60 mm Hg on PSG were strong and more consistent predictors of postoperative respiratory complications than AHIs. However, these values should not be considered absolute cutoffs, especially as ROC models failed to precisely define populations at risk, and thus, clinical judgment is still needed to determine which children with OSAS should have surgery at an ambulatory or pediatric hospital site and which should be admitted after adenotonsillectomy.

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References

1. Lumeng JC, Chervin RD. Epidemiology of pediatric obstructive sleep apnea. Proc Am Thorac Soc. 2008; 5:242–252. [PubMed: 18250218]
2. Marcus CL, Brooks LJ, Draper KA, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome: clinical practice guideline. Pediatrics. 2012; 130:576–584. [PubMed: 22926173]
3. Mitchell RB, Kelly J. Outcome of adenotonsillectomy for obstructive sleep apnea in obese and normal-weight children. Otolaryngol Head Neck Surg. 2007; 137:43–48. [PubMed: 17599563]
4. Costa DJ, Mitchell R. Adenotonsillectomy for obstructive sleep apnea in obese children: a meta-analysis. Otolaryngol Head Neck Surg. 2009; 140:455–460. [PubMed: 19328330]
5. Statham MM, Elluru RG, Buncher R, Kalra M. Adenotonsillectomy for obstructive sleep apnea syndrome in young children: prevalence of pulmonary complications. Arch Otolaryngol Head Neck Surg. 2006; 132:476–480. [PubMed: 16702561]
6. Leong AC, Davis JP. Morbidity after adenotonsillectomy for paediatric obstructive sleep apnoea syndrome: waking up to a pragmatic approach. J Laryngol Otol. 2007; 121:809–817. [PubMed: 17553183]
7. Ye J, Liu H, Zhang G, Huang Z, Huang P, Li Y. Postoperative respiratory complications of adenotonsillectomy for obstructive sleep apnea syndrome in older children: prevalence, risk factors, and impact on clinical outcome. J Otolaryngol Head Neck Surg. 2009; 38:49–58. [PubMed: 19344613]
8. Tweedie DJ, Bajaj Y, Ifeacho SN, et al. Peri-operative complications after adenotonsillectomy in a UK pediatric tertiary referral centre. Int J Pediatr Otorhinolaryngol. 2012; 76:809–815. [PubMed: 22469495]
9. Robb PJ, Ewah BN. Post-operative nausea and vomiting following paediatric day-case tonsillectomy: audit of the Epsom protocol. J Laryngol Otol. 2011; 125:1049–1052. [PubMed: 21774846]
10. Rosen GM, Muckle RP, Mahowald MW, Goding GS, Ullevig C. Postoperative respiratory compromise in children with obstructive sleep apnea syndrome: can it be anticipated? Pediatrics. 1994; 93:784–788. [PubMed: 8165079]

11. Hill CA, Litvak A, Canapari C, et al. A pilot study to identify pre- and peri-operative risk factors for airway complications following adenotonsillectomy for treatment of severe pediatric osa. Int J Pediatr Otorhinolaryngol. 2011; 75:1385–1390. [PubMed: 21871668]
12. Schroeder JW Jr, Anstead AS, Wong H. Complications in children who electively remain intubated after adenotonsillectomy for severe obstructive sleep apnea. Int J Pediatr Otorhinolaryngol. 2009; 73:1095–1099. [PubMed: 19467719]
13. Nixon GM, Kermack AS, Mcgregor CD, et al. Sleep and breathing on the first night after adenotonsillectomy for obstructive sleep apnea. Pediatr Pulmonol. 2005; 39:332–338. [PubMed: 15704184]
14. Mccolley SA, April MM, Carroll JL, Loughlin GM. Respiratory compromise after adenotonsillectomy in children with obstructive sleep apnea. Arch Otolaryngol Head Neck Surg. 1992; 118:940–943. [PubMed: 1503720]
15. Goyal SS, Shah R, Roberson DW, Schwartz ML. Variation in post-adenotonsillectomy admission practices in 24 pediatric hospitals. Laryngoscope. 2013; 123:2560–2566. [PubMed: 23907959]
16. Mitchell RB, Pereira KD, Friedman NR. Sleep-disordered breathing in children: survey of current practice. Laryngoscope. 2006; 116:956–958. [PubMed: 16735907]
17. Gross JB, Bachenberg KL, Benumof JL, et al. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: a report by the American Society of Anesthesiologists Task Force on perioperative management of patients with obstructive sleep apnea. Anesthesiology. 2006; 104:1081–1093. [PubMed: 16645462]
18. Roland PS, Rosenfeld RM, Brooks LJ, et al. Clinical practice guideline: polysomnography for sleep-disordered breathing prior to tonsillectomy in children. Otolaryngol Head Neck Surg. 2011; 145:S1–S15. [PubMed: 21676944]
19. Sanders JC, King MA, Mitchell RB, Kelly JP. Perioperative complications of adenotonsillectomy in children with obstructive sleep apnea syndrome. Anesth Analg. 2006; 103:1115–1121. [PubMed: 17056942]
20. Marcus CL, Omlin KJ, Basinki DJ, et al. Normal polysomno-graphic values for children and adolescents. Am Rev Respir Dis. 1992; 146:1235–1239. [PubMed: 1443877]
21. Witmans MB, Keens TG, Davidson Ward SL, Marcus CL. Obstructive hypopneas in children and adolescents: normal values. Am J Respir Crit Care Med. 2003; 168:1540. [PubMed: 14668259]
22. Traeger N, Schultz B, Pollock AN, Mason T, Marcus CL, Arens R. Polysomnographic values in children 2-9 years old: additional data and review of the literature. Pediatr Pulmonol. 2005; 40:22–30. [PubMed: 15858805]
23. Uliel S, Tauman R, Greenfeld M, Sivan Y. Normal polysomnographic respiratory values in children and adolescents. Chest. 2004; 125:872–878. [PubMed: 15006944]
24. Iber, C., editor. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specification. American Academy of Sleep Medicine; Darien, Illinois: 2007.
25. Wise MS, Nichols CD, Grigg-Damberger MM, et al. Executive summary of respiratory indications for polysomnography in children: an evidence-based review. Sleep. 2011; 34:389–398. [PubMed: 21359088]
26. Wilson K, Lakheeram I, Morielli A, Brouillette R, Brown K. Can assessment for obstructive sleep apnea help predict postadenotonsillectomy respiratory complications? Anesthesiology. 2002; 96:313–322. [PubMed: 11818762]
27. Brown KA, Laferriere A, Moss IR. Recurrent hypoxemia in young children with obstructive sleep apnea is associated with reduced opioid requirement for analgesia. Anesthesiology. 2004; 100:806–810. [PubMed: 15087614]
28. Jaryszak EM, Shah RK, Vanison CC, Lander L, Choi SS. Polysomnographic variables predictive of adverse respiratory events after pediatric adenotonsillectomy. Arch Otolaryngol Head Neck Surg. 2011; 137:15–18. [PubMed: 21242540]
29. Richmond KH, Wetmore RF, Baranak CC. Postoperative complications following tonsillectomy and adenoidectomy: who is at risk? Int J Pediatr Otorhinolaryngol. 1987; 13:117–124. [PubMed: 3667091]

30. Redline S, Tishler PV, Schluchter M, Aylor J, Clark K, Graham G. Risk factors for sleep-disordered breathing in children: associations with obesity, race, and respiratory problems. Am J Respir Crit Care Med. 1999; 159:1527–1532. [PubMed: 10228121]
31. Marcus CL, Moore RH, Rosen CL, et al. A randomized trial of adenotonsillectomy for childhood sleep apnea. N Engl J Med. 2013; 368:2366–2376. [PubMed: 23692173]
32. Weinstock TG, Rosen CL, Marcus CL, et al. Predictors of obstructive sleep apnea severity in adenotonsillectomy candidates. Sleep. 2014; 37:261–269. [PubMed: 24497655]
33. Goh DYT, Galster P, Marcus CL. Sleep architecture and respiratory disturbances in children with obstructive sleep apnea. Am J Respir Crit Care Med. 2000; 162:682–686. [PubMed: 10934106]
34. Raghavendran S, Bagry H, Detheux G, Zhang X, Brouillette RT, Brown KA. An anesthetic management protocol to decrease respiratory complications after adenotonsillectomy in children with severe sleep apnea. Anesth Analg. 2010; 110:1093–1101. [PubMed: 20142343]
35. Brown KA, Laferriere A, Lakheeram I, Moss IR. Recurrent hypoxemia in children is associated with increased analgesic sensitivity to opiates. Anesthesiology. 2006; 105:665–669. [PubMed: 17006062]

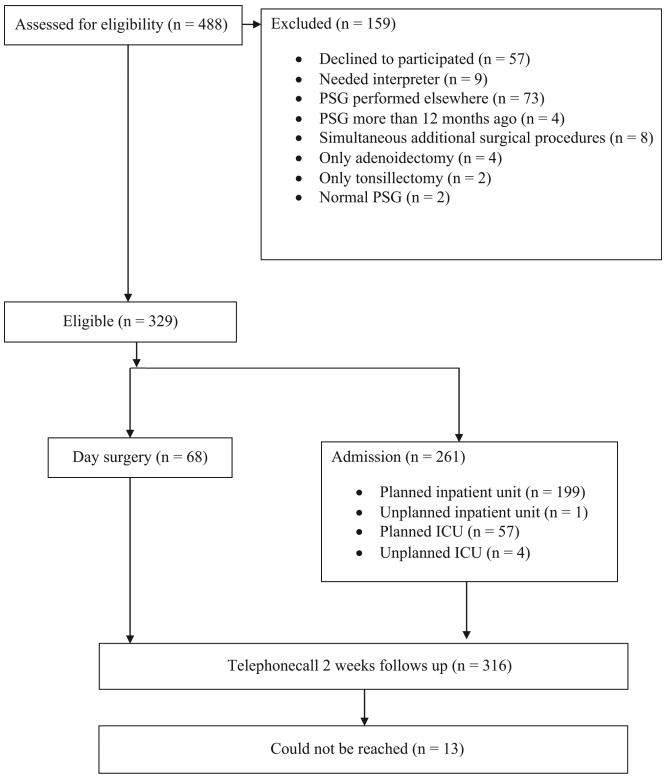

Figure 1.
The study flow is shown.

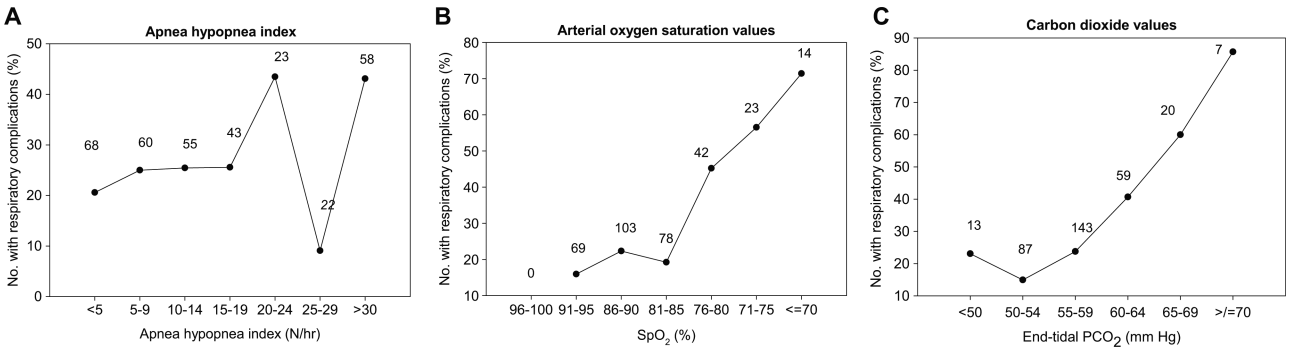

Figure 2.

The percentage of patients with respiratory complications at each level of apnea hypopnea index (A), arterial oxygen saturation nadir (B), and peak end-tidal CO_2 (C) is shown.

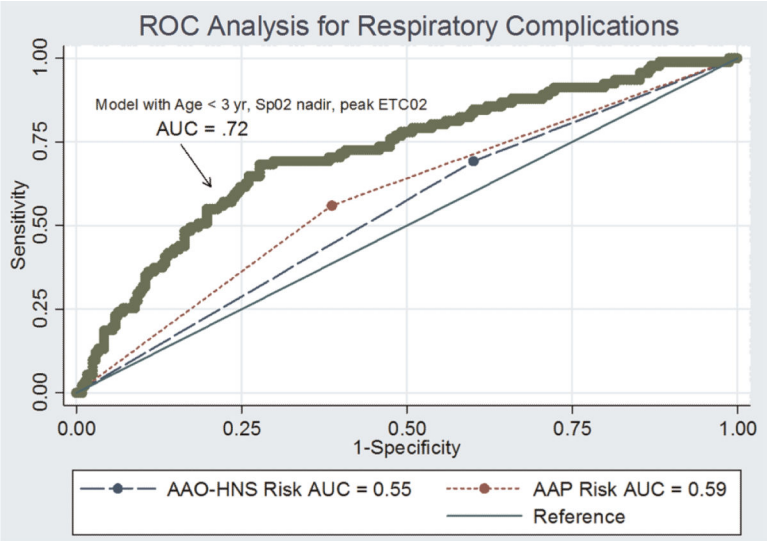

Figure 3.

The receiver operating characteristic (ROC) curve is shown for the current model (age <3 years, SpO_2 nadir, and peak CO_2) in green. The reference curve and curves for the American Academy of Pediatrics (AAP; dotted line) and American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNSF; dashed line) criteria are shown for comparison. The number of patients at each level is shown above each point of the graph.

Table 1

Incidence of Nonrespiratory Complications.

Nonrespiratory Complications	Total, n (%)	≤24 h, n	>24 h, n
Immediately postoperatively			
Any bleeding	3 (0.9)	2	1
Required reoperation	2 (0.6)	2	0
Poor oral intake	58 (17.6)	11	47
Dehydration	2 (0.6)	0	2
Cardiac instability (sinus bradycardia)	1 (0.3)	1	0
Within 2 weeks after discharge			
Any bleeding	18 (5.5)		
Bleeding requiring reoperation	6 (1.8)		
Fever	9 (2.7)		
Dehydration	26 (7.9)		
Required readmission	3 (0.9)		
Poorly controlled pain requiring increased dose or duration of medication	8 (2.4)		
Poorly controlled nausea and vomiting requiring return to emergency department and need for ondansetron	2 (0.6)		

Table 2

Complications in High-Risk Subgroups.

	All Major and Minor Respiratory Complications		Major Respiratory Complications		Nonrespiratory Complications	
Subgroups (n)	**n (%)**	***P* Value**[a]	**n (%)**	***P* Value**[a]	**n (%)**	***P* Value**[a]
Age		**.002**		<.0005		.69
<3 y (89)	36 (40.4)		26 (29.2)		31 (34.8)	
>3 y (240)	55 (22.9)		29 (12.1)		77 (32.1)	
Race		**.036**		.083		.71
Black (108)	38 (35.2)		24 (22.2)		37 (34.3)	
Other (221)	53 (24.0)		31 (14.0)		71 (32.1)	
Obesity		.31		.73		.89
Obese (78)	25 (32.1)		14 (17.9)		26 (33.3)	
Nonobese (246)	64 (26.0)		39 (15.9)		79 (32.1)	
Failure to thrive		.13		.039		.096
Yes (29)	12 (41.4)		9 (31.0)		14 (48.3)	
No (300)	79 (26.3)		46 (15.3)		94 (31.3)	
Prematurity		.61		.84		.19
Premature (52)	16 (30.8)		9 (17.3)		21 (40.4)	
Full term (235)	63 (26.8)		37 (15.7)		72 (30.6)	
Medical comorbidities		.22		.55		.41
Other comorbidities (141)	44 (31.2)		26 (18.4)		50 (35.5)	
No comorbidities (188)	47 (25.0)		29 (15.4)		58 (30.9)	

[a]From the Fisher exact test. Significant *P* values are shown in bold.

Table 3

Descriptives and Rank-Biserial Correlation Coefficients between Polysomnographic Findings and Perioperative Complications.

	All Major and Minor Respiratory Complications		Major Respiratory Complications		Nonrespiratory Complications	
	Median (Minimum-Maximum)	Correlation Coefficient (*P* Value)	Median (Minimum-Maximum)	Correlation Coefficient (*P* Value)	Median (Minimum-Maximum)	Corre Coeff (*P* V
Arousal index, n/h		0.082 (.25)		0.13 (.14)		–0.03
Yes	18.3 (6.5-87.9)		20.2 (7.5-87.9)		17.6 (5.5-87.9)	
No	17.9 (4.2-70.5)		17.7 (4.2-70.5)		18.3 (4.2-70.5)	
Apnea hypopnea index, n/h		0.174 (.017)		0.329 (<.0005)		–0.01
Yes	16.5 (2.3-166.3)		19.8 (2.5-166.3)		13.4 (0.5-166.3)	
No	13.0 (0.5-111.7)		12.0 (0.5-112.6)		13.3 (1.7-123.5)	
SpO_2 nadir, %		–0.332 (<.0005)		–0.391 (<.0005)		–0.03
Yes	82 (51-93)		80 (51-93)		85 (65-95)	
No	87 (56-95)		87 (56-95)		86 (51-95)	
Total sleep time with SpO_2 <90%, %		0.298 (<.0005)		0.430 (<.0005)		0.055
Yes	1.1 (0.0-34.8)		1.4 (0.0-34.7)		0.3 (0.0-35.4)	
No	0.1 (0.0-82.3)		0.15 (0.0-82.3)		0.2 (0.0-82.3)	
Peak end-tidal CO_2, mm Hg		0.354 (<.0005)		0.448 (<.0005)		0.043
Yes	59.1 (44.8-73.0)		60.2 (44.8-73.0)		56.9 (44.2-71.1)	
No	56.1 (44.2-70.1)		56.2 (44.2-70.1)		56.6 (46.2-73.0)	
Total sleep time with end-tidal CO_2 >50 mm Hg, %		0.199 (.006)		0.319 (<.0005)		0.034
Yes	17.4 (0.0-99.2)		25.1 (0.0-99.2)		9.4 (0.0-97.7)	
No	7.6 (0.0-98.6)		7.6 (0.0-98.6)		8.2 (0.0-99.2)	

Table 4

Logistic Regression Models for Perioperative Respiratory Complications (Presence or Absence).

Covariate	OR	SE	*P* Value	95% CI	AUC
Models for Separate Demographic and Polysomnographic Variables					
Age <3 y	2.285	0.605	.002	1.359-3.841	0.586
Arousal index	1.015	0.010	.14	0.996-1.035	0.541
Apnea hypopnea index	1.018	0.006	.002	1.007-1.029	0.587
SpO_2 nadir	0.915	0.017	<.0005	0.883-0.948	0.666
Peak end-tidal CO_2	1.150	0.032	<.0005	1.089-1.214	0.677
% of total sleep time with end-tidal CO_2 >50 mm Hg	1.016	0.005	.001	1.007-1.025	0.600
% of total sleep time with SpO_2 <90%	1.066	0.023	.003	1.022-1.113	0.649
AAP Model					
AAP risk (yes)	2.005	0.500	.005	1.230-3.270	0.586
AAO-HNSF Model					
AAO-HNSF risk (yes)	1.495	0.393	.13	0.893-2.502	0.546
Proposed Model Based on Current Data					
Age <3 y	2.249	0.636	.004	1.292-3.914	0.721
SpO_2 nadir	0.948	0.020	.011	0.910-0.988	
Peak CO_2	1.102	0.036	.003	1.035-1.174	

Abbreviations: AAO-HNSF risk, meets polysomnographic admission criteria from the American Academy of Otolaryngology—Head and Neck Surgery Foundation; AAP risk, meets polysomnographic admission criteria from the American Academy of Pediatrics; AUC, area under the curve; CI, confidence interval; OR, odds ratio; SE, standard error of the odds ratio.