The Laryngoscope

Tonsillectomy for Obstructive Sleep-Disordered Breathing: Should They Stay, or Could They Go?

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Objectives/Hypothesis: Children who do not require oxygen beyond 3 hours after surgery and pass a sleep room air challenge (SRAC) are safe for discharge regardless of polysomnogram (PSG) results or comorbidities.

Study Design: Cross-sectional prospective study.

Methods: All children observed overnight undergoing an adenotonsillectomy for obstructive sleep-disordered breathing were prospectively recruited. Demographic, clinical, and PSG characteristics were stratified by whether the patient had required oxygen beyond 3 hours postoperatively (prolonged oxygen requirement [POR]) and compared using *t* test, chi-squared test, or Fisher's exact test depending on distribution. Optimal cut points for predicting POR postsurgery were calculated using receiver operating characteristic curves. The primary analysis was performed on the full cohort via logistic regression using POR as the outcome. Significant characteristics were analyzed in a logistic regression model, with significance set at $P < .05$.

Results: A total of 484 participants met the inclusion criteria. The mean age was 5.65 (standard deviation = 4.02) years. Overall, 365 (75%) did not have a POR or any other adverse respiratory event. In multivariable logistic regression, risk factors for POR were an asthma diagnosis ($P < .001$) and an awake SpO_2 <96% ($P = .005$). The probability of a POR for those without asthma and a $SpO_2 \geq 96\%$ was 18% (95% confidence interval: 14–22). Age, obesity, and obstructive apnea/hypopnea index were not associated with POR.

Conclusions: In conclusion, all children in our study who are off oxygen within 3 hours of surgery and passed a SRAC were safe for discharge from a respiratory standpoint regardless of age, obesity status, asthma diagnosis, and obstructive apnea/hypopnea index. Additional investigations are necessary to confirm our findings.

Key Words: Obstructive sleep-disordered breathing, obstructive sleep apnea, tonsillectomy, child, complications.

Level of Evidence: 3

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INTRODUCTION

Tonsillectomy with or without adenoidectomy (T&A) is a common surgical procedure, and the primary indication is often obstructive sleep-disordered breathing (oSDB).[1] While oSDB is based on clinical assessment, obstructive sleep apnea (OSA) requires polysomnography (PSG), an objective nocturnal test of children's breathing patterns.[2] Clinical practice guidelines (CPGs) rely on PSG findings to determine who should be monitored overnight,[2,3] but they do not discuss discharge criteria for same-day surgery. There is a large variation in post-T&A admission rates,[4] as well as the amount of time a child is observed postoperatively.[5] A limitation of American Academy of Otolaryngology/Head and Neck Surgery CPG overnight monitoring criteria is that they are based on investigations from over 15 years ago.[6,7] Furthermore, the criteria for significant desaturation events vary by the institution.[7–9] An evidence gap exists in the management of children undergoing a T&A for oSDB.

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Clinically, most children do not undergo a preoperative PSG.[10] Without a PSG, surgeons rely on clinical criteria to select children for overnight observation. Unfortunately, multiple studies have reported that clinicians are unable to predict the OSA severity by clinical criteria.[11–14] In the Childhood Adenotonsillectomy study, only 50% of the children enrolled in the study were confirmed to have OSA by overnight PSG.[14] If clinicians are unable to predict the presence or absence of OSA, it is even less likely they can predict OSA severity. Since PSG is inconsistently performed, an obstructive apnean/hypopnea index (OAHI) and a SpO_2 nadir are oftentimes unavailable to guide perioperative planning. Outcomes data based on non-PSG metrics would aid in decision making for all children undergoing T&A and assist in fulfilling the Institute of Healthcare Improvement's aim of improving the patient care experience while reducing costs.

Our objective is to determine a pragmatic, evidence-based approach to decide which "high-risk" children are unlikely to benefit from overnight observation and whether a prolonged oxygen requirement (POR) is a safe criterion to determine the need for overnight monitoring. Our hypothesis is that children who do not have a POR (i.e., do not require oxygen beyond 3 hours after surgery) and pass a sleep room air challenge (SRAC) are safe for discharge regardless of PSG results or comorbidities.

MATERIALS AND METHODS

Colorado Multiple Institutional Review Board (COMIRB) approval was obtained (COMIRB #17-1686).

Children undergoing a total T&A for oSDB aged 1–18 years from May 2018 to June 2019 who were being observed overnight were consented and enrolled. The exclusion criteria were any child undergoing a nonotolaryngologic procedure during the same anesthetic or if preoperative PSG revealed a preexisting oxygen requirement (SpO_2 was <90% for >2% of the total sleep time). An a priori power calculation showed a sample size of 484 participants achieves 80% power to detect a difference as small as 5% between participants experiencing a POR as compared to those being on room air within 3 hours following extubation using a two-sided exact test with a significance level (alpha) of .05.

The standard T&A management protocol at our institution is highlighted in Figure 1. The provider designates if a child is "high" or "low" risk when ordering surgery. High-risk children include age <3 years, severe OSA (OAHI ≥10 and/or SpO_2 nadir ≤80%), neuromuscular disorder, complex cardiac disease, or clinical suspicion by surgeon. All obese children are considered "high risk" unless a PSG demonstrates nonsevere OSA.[2] High-risk children are scheduled for overnight monitoring, and all T&A patients are monitored in the postanesthesia care unit (PACU) following surgery. A successful SRAC is defined as maintaining a SpO_2 of ≥90% for a minimum of 20 minutes. Brief SpO_2 desaturations to 85% are allowed. Low-risk subjects are observed overnight for the following reasons: unsuccessful SRAC, poor pain control or inadequate oral intake. The "high-risk" children who still have an oxygen requirement upon arrival to the ward are placed on room air immediately to determine if they still require oxygen while awake. As part of the standardized postoperative orders, only children ≥5 years of age are prescribed narcotics on the ward. Room air challenges (RAC) on the ward are performed every 2 hours until the child has a successful awake RAC or SRAC.

Demographic information was collected, and the guardian completed a validated pediatric sleep questionnaire (PSQ).[15] Additional preoperative variables included surgical indications, comorbidities, and preoperative awake SpO_2. The body mass index (BMI) percentile for age/sex was calculated per the CDC guidelines. Obesity was further classified using the BMI expressed as a percentage of the 95th percentile by sex and age (%BMIp95). Children with a BMI ≥120% were categorized as severely obese.[16] PSG characteristics collected included sleep architecture, respiratory events, mean awake and asleep SpO_2, SpO_2 nadir, and peak end-tidal carbon dioxide. Preoperative OSA severity was categorized by the OAHI into the following: primary snoring (<1), mild/moderate (1 to <10), severe (≥10), and very severe (≥24) OSA.[2,3] The Brodsky grading scale was used to categorize tonsil size. Opioid administration within 90 minutes after extubation was also collected.

The primary outcome measure was oxygen status 3 hours following extubation. A POR was defined as being either on oxygen for greater than 3 hours or off oxygen at 3 hours but subsequently needing supplemental oxygen beyond the three-hour mark. The decision to define a POR as greater than 3 hours was based on observation periods typically being at least 2 hours, major respiratory events oftentimes occurring within 2 hours, and an observation period >3 hours being problematic for same-day surgery units.[5,17,18] The protocol at our institution is to start

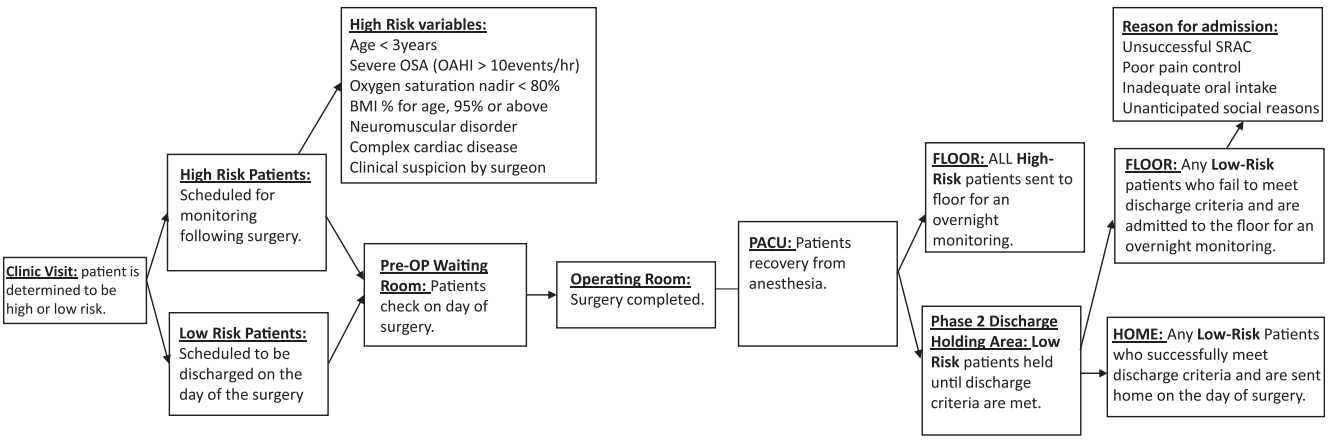

Fig. 1. Flow diagram of the clinical course for a child undergoing a tonsillectomy and adenoidectomy.

supplemental oxygen for a SpO_2 persistently below 90%. Other postoperative respiratory adverse events (PRAE) include positive pressure ventilation, respiratory depression requiring intervention, PICU admission, and postobstructive pulmonary edema.

Study data were stored using the Research Electronic Data Capture (REDCap) system hosted at our institution.[19] Demographic, clinical, and PSG characteristics were stratified by whether the patient had a POR and compared using *t* test, chi-squared test, or Fisher's exact test depending on distribution. Optimal cut points to predict a POR were calculated using receiver operator characteristic (ROC) curves for mean awake preoperative SpO_2 and the following PSG variables: SpO_2 nadir, mean awake and asleep SpO_2. The primary analysis was performed on the full cohort via logistic regression on comparing presence or absence of POR adjusting for statistically significant covariates. All demographic and clinical characteristics were considered for the model using a significance cutoff value of .05. A sub-analysis was performed on those children who had a preoperative PSG. A *P*-value of .05 was used as the cutoff for significance. Risk percentages were calculated from the final models. All cleaning, summarizing, and analysis was performed using the statistical software platform, R.[20]

RESULTS

A total of 558 children were initially screened, and 484 met the inclusion criteria (see Fig. 2). Demographics are stratified by POR in Table 1. There were 351 (72.5%) children that had no concomitant procedure, while the remainder had a T&A with other otolaryngologic surgery (see Table 2). Concomitant procedures in addition to a T&A ($P = .253$) and PSQ score ($P = .184$) were not associated with a POR. Overall, 365 (75%) children did not have a POR, and 336 (69%) children were off oxygen at 2 hours. None of the children who were off oxygen at 2 hours went back on oxygen for the entire monitoring

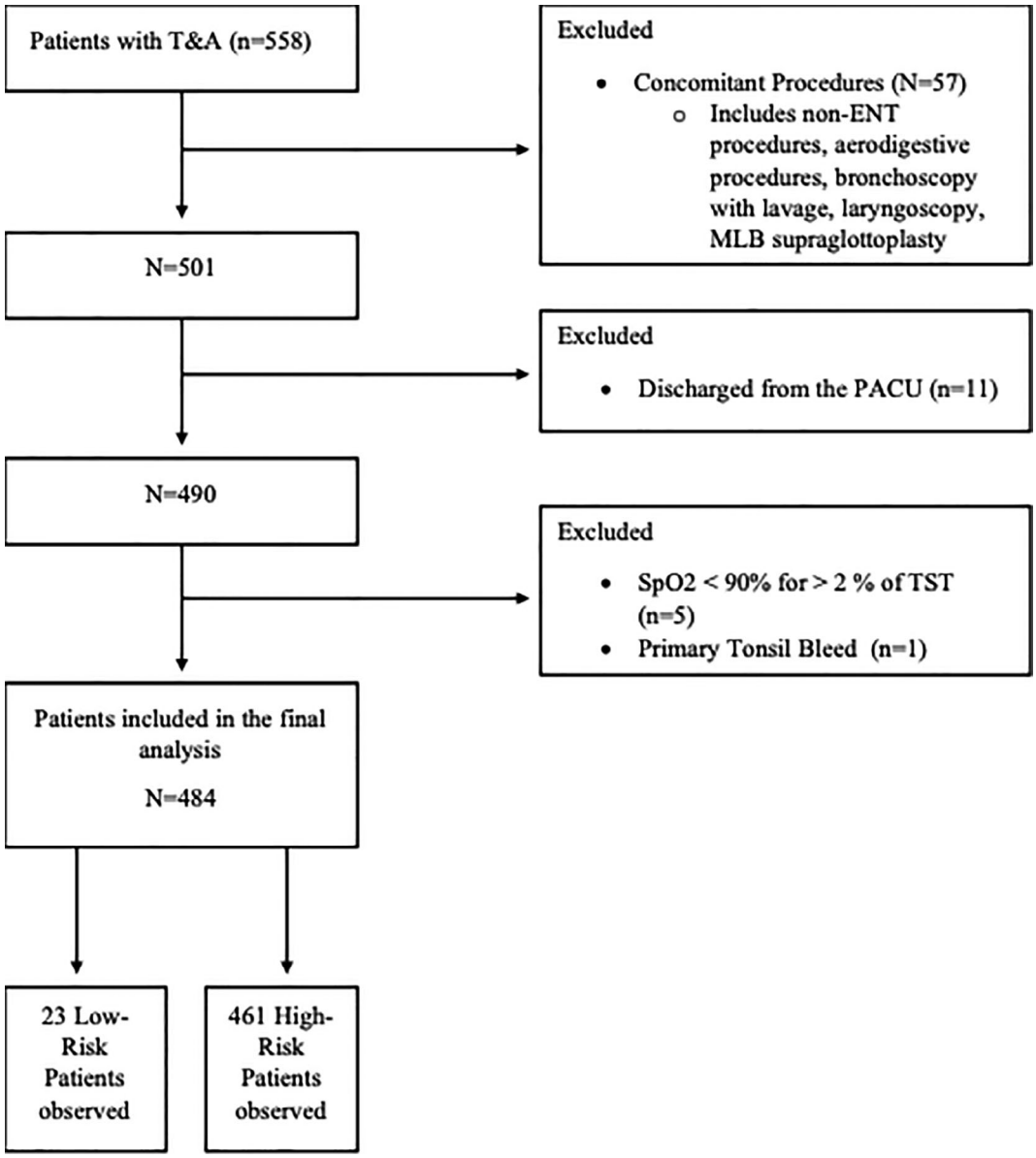

Fig. 2. Consort diagram for the study.

TABLE 1.
Demographics and Clinical Characteristics Stratified by Oxygen Status at 3 Hours.

	POR (n = 119)	No POR (n = 365)	Total (n = 484)	*P* Value
Sex				
Male	67 (24.2%)	210 (75.8%)	277	.897
Female	52 (25.1%)	155 (74.8%)	207	
Age				
Under 3 years	31 (26.5%)	86 (73.4%)	117	.669
Over 3 years	88 (24.0%)	279 (76.0%)	367	
Obesity				
Nonsevere	17 (18.5%)	75 (81.5%)	92	.357
Severe	26 (26.8%)	71 (73.2%)	97	
Normal weight	68 (24.8%)	206 (75.2%)	274	
Race				
Asian	1 (12.5%)	7 (87.5%)	8	.367
Black	5 (19.2%)	21 (80.8%)	26	
Other	31 (20.9%)	117 (79.1%)	148	
White	82 (27.2%)	220 (72.8%)	302	
Ethnicity				
Hispanic or Latino	36 (22.4%)	125 (77.6%)	161	.473
Not Hispanic or Latino	76 (26.5%)	211 (73.5%)	287	
Unknown	7 (19.4%	29 (80.6%)	36	
Tonsil size	3.16 (0.60)	3.11 (0.63)	3.12 (0.62)	.477
Diagnosis				.981
Premature	2 (33.3%)	4 (66.7%)	6	.639
Asthma	31 (38.3%)	50 (61.7%)	81	**.003**
Down syndrome	11 (45.8%)	13 (54.2%)	24	**.025**
Cardiac disease	9 (39.1%)	14 (60.9%)	23 (4.8%)	.158
Concomitant procedure				
No	82 (23.1%)	273 (76.9%)	355	.253
Yes	37 (30.8%)	92 (76.7%)	120	
Awake oxygen saturation				
≥96%	66 (19.8%)	267 (80.2%)	333	**<.001**
<96%	53 (36.6%)	92 (63.4%)	145	
Opioids within 90 min of surgery				
No	21 (21.9%)	75 (78.1%)	96	.578
Yes	98 (25.3%)	290 (74.7%)	388	
PSQ score categorical				
≥0.33	106 (25.7%)	307 (74.3%)	413	.184
<0.33	13 (18.3%)	58 (82.7%)	71	

Bold numbers are statistically significant.

period. Of the 119 children with a POR, three (2.5%) children were off oxygen at 3 hours but subsequently went back on oxygen after failing their first SRAC. There were no PRAEs for children who did not experience a POR. Twenty-three (4.7%) "low-risk" patients were observed overnight: 16 (3.3%) failed a SRAC either in phase 2 or discharge area; six (1.2%) for social reasons; and one for emesis.

An asthma diagnosis ($P = .003$) and Down syndrome ($P = .025$) were statistically significant variables in predicting whether a child would have a POR. A ROC analysis found that the preoperative awake SpO_2 optimal cutoff value was 96.0%, with an AUC of 0.61. A logistic regression model was created that included only the statistically significant variables of preoperative awake SpO_2 and asthma diagnosis. In this analysis, a child with an asthma diagnosis was 2.08 (95% confidence interval [CI]: 1.23–3.48) more likely to have a POR compared to a child without asthma, and those with an awake SpO_2 <96% were 2.27 (95% CI: 1.46–3.51) more likely to have a POR compared to those with an awake SpO_2 ≥96%. If a child did not have asthma and had an awake SpO_2 ≥96%, the probability of a POR was 18% (95% CI: 14–22). By awake SpO_2 ≥96% alone, there was a 20% probability of a POR. Age, obesity, and OSA severity were not significantly associated with POR. In total, 51 children with

TABLE 2.
Concomitant Otolaryngologic Surgical Procedures Performed.

Concomitant Procedure	Number of Patients (n = 129)
ABR (auditory brain response)	2
Drug induced sleep endoscopy with dexmedetomidine	3
Frenulectomy	4
Examination under anesthesia—ears	19
Microlaryngoscopy/bronchosciot	6
Myringotomy	3
Nasal endoscopy	3
Turbinate reduction	15
Tympanotomy and tube insertion	39
More than one of the above procedures in addition to the T&A	35

asthma had an awake SpO_2 ≥96%, and 14 of them had a POR. For the 30 children with both asthma and an awake SpO_2 <96%, there were 17 who had a POR.

Preoperative PSG within 6 months of surgery was performed on 232 (48%) children. A SpO_2 nadir of <80% ($P = .003$), awake mean SpO_2 <95.4% ($P < .001$), and asleep mean SpO_2 <94.6% ($P = .003$) were statistically significantly associated with a POR.

Besides a POR incidence of 25%, there were three other PRAEs. Three children required brief bag mask ventilation in the PACU. No child required reintubation or transfer to the intensive care unit (ICU). An analysis of whether opioids being administered within 90 minutes after the end of the procedure did not show any association with a POR ($P = .578$).

DISCUSSION

Perioperative morbidity associated with a T&A is low.[21–23] Our investigation suggests that approximately 75% of "high-risk" children do not require overnight monitoring. Over 66% of the cohort were on room air within 2 hours of extubation. The presence of asthma and an awake SpO_2 <96% were the only variables significantly associated with a POR. Age, obesity, and OAHI were not associated with a POR. Our hypothesis was correct in that children who are off oxygen within 3 hours of extubation in our study did not require overnight monitoring from a respiratory standpoint once they have passed a 20-minute SRAC. An SRAC is important since sleep will unmask respiratory insufficiency and be a warning sign that a longer observation period is warranted. Overall, our investigation suggests that the overnight monitoring criteria for children with oSDB may be too stringent. Rather than mandatory overnight observation, we are advocating for a paradigm shift where "high-risk" children including those who have an elevated OAHI have surgery at a facility that could perform overnight monitoring if needed. Potentially, these children could be observed in a stepdown area to determine if they are safe for discharge. Since the need for supplemental oxygen requires overnight observation, those children with a lower baseline SpO_2 prior to surgery should be deemed at elevated risk for overnight monitoring. As for children with asthma, they could be optimized preoperatively which may reduce the need for prolonged monitoring. Although the outcome metric to determine a POR was 3 hours, no child who was on room air by 2 hours and passed a SRAC went back on oxygen, so these children do not require additional monitoring beyond the 2-hour mark.

A major factor in determining the safety of outpatient surgery is the frequency and timing of severe PRAEs. In a 2006 survey of ambulatory surgery data of approximately 480,000 tonsillectomies performed in both hospitals based and free-standing centers, PRAEs were rare. Airway obstruction was documented in 0.18% in children <4 years of age and only in 0.05% for older children.[21] In our investigation, the most common PRAE was a POR. Twenty-five percent of the cohort had a POR, of which only three children were off oxygen at 3 hours. These three children were placed back on oxygen during their first SRAC. There were only three other PRAEs which required airway intervention in the PACU. No child required intubation. Seventy-five percent had an uneventful hospital stay and could have been safely discharged after the observation period.

The lack of standard criteria to define PRAEs undermines T&A outcome research. SpO_2 desaturations are a common PRAE; unfortunately, the threshold for what constitutes a significant desaturation is variable.[7–9] Defining a significant SpO_2 desaturation to be below 90%, 92%, or 95%, varies the PRAE prevalence to 1.6%, 3.6%, and 11.6%, respectively.[9] For oSDB children, desaturation below 95% is probably a preexisting condition. Our definition of a significant desaturation required an intervention. At our institution, children are administered supplemental oxygen for a SpO_2 persistently below 90%. Our findings are consistent with an analysis of over 140,000 inpatients where the PRAE incidence was only 1.3%.[22] Our data suggest that, rather than mandate overnight monitoring for high-risk patients, resources may be more efficiently used by performing high-risk tonsillectomies at day-surgery facilities with access to overnight monitoring if needed, and allowing for discharge after an observation period with a successful SRAC.

Since most children do not have preoperative PSG, we sought to explore whether easily accessible clinical variables could predict PRAEs. Age, obesity status, prematurity, race, and comorbidities have all been associated with PRAEs.[6,23–27] Other potential clinical predictors include PSQ score, an awake SpO_2, and tonsil grade. A PSQ score ≥33% suggests that a child has at least moderate OSA. The awake SpO_2 provides an estimate of a child's baseline pulmonary status. A child with a higher baseline SpO_2 would be less likely to have an oxygen desaturation following a short apnea.[28] In our cohort, the only variables that were associated with a POR were Down syndrome, asthma, and awake SpO_2 <96%. The association of asthma and POR is consistent with other studies showing increased PRAEs for these patients.[29]

A consistent recommendation is that children under 3 years of age should be monitored overnight. Like other investigations, younger children in our study did not have more PRAEs.[30–32] Potentially, an age requirement is unnecessary from a respiratory standpoint; however, the necessity of prolonged observation for oral intake was not assessed.

Besides age, multiple studies have implicated obesity to be a risk factor for PRAEs.[24,33] In contrast to other studies, our investigation showed that obesity was not predictive of PRAEs. Since obesity is associated with lower lung volumes, one would suspect children with more severe obesity would have a higher incidence of PRAEs.[34] Obesity is associated with a reduced functional residual capacity resulting in a lower oxygen reserve and quicker SpO_2 desaturations during an obstructive event.[34] The awake SpO_2 is potentially a strong surrogate for a child's pulmonary reserve and a better predictor for a PRAE than one's obesity severity.

The PSG metric of an SpO_2 nadir <80% was predictive of a POR but not the OAHI. Children with mild/moderate OSA (OAHI <10) were just as likely as those who had very severe OSA (OAHI ≥24) to have a POR which mirrors Kang's finding.[9] The inability for OAHI severity to predict POR in our investigation is not surprising. The challenge of stratifying OSA severity to a single number is the variability inherent in the OAHI. Airflow sensor reliability may be compromised by poor tolerance or mouth breathing. The OAHI may be positional or related to rapid eye movement sleep.[35,36] Furthermore, in 2012 a hypopnea was redefined to require only a 30% reduction in airflow which increases the number of scoreable hypopneas.[37] Overall, those investigations from over 15 years ago that established an OAHI cutoff are less relevant today.[6,7]

In summary, the OAHI establishes that a child has OSA but does not predict one's postoperative course.

A major strength of this investigation was adoption of a standardized T&A management algorithm, which included criteria for inpatient monitoring and postoperative care. Overall, the inclusion criteria were broad and included children with concomitant otolaryngologic surgery, Down syndrome, and severe obesity. Obesity severity was quantified using the %BMIp95, which expanded the maximal value above 99% and enabled a more detailed analysis of the influence of weight on outcomes. Overall, over 80% had an elevated PSQ score, which suggests these children had at least moderate OSA. By limiting the exclusions, our cohort is diverse, and these characteristics increase generalizability of the data.

Our investigation does have limitations. First, our institution does not have a dedicated research ward. Multiple nurses cared for T&A patients, and although there are defined parameters on RACs and initiation of oxygen, some variability in care will occur. Second, all children underwent electrocautery T&A. Third, opioids are restricted on the ward. Only children at least 5 years of age are prescribed an as-needed dose of oxycodone at 0.05 mg/kg. The influence of opioids for the perioperative course is unknown for younger children in this cohort. Fourth, our institution is above sea level. At higher altitudes, the partial pressure of oxygen (pO_2) is lower. Children are more likely to have desaturations following briefer apneas.[28] Subsequently, our cohort potentially has a higher chance of a POR due to a lower baseline pO_2. Finally, this study was a single center study, so additional studies at outside institutes will need to be done to validate our findings.

Overall, when making recommendations regarding the disposition of a child following surgery, one needs to err on the side of caution. The implications of our investigation for clinical practice is that some children who are being observed overnight may be candidates for same-day surgery. Our investigation suggests that even children with severe obesity are unlikely to have PRAEs. Rather than a reflexive decision to admit all "high-risk" children, we advocate that a clinical decision is made postoperatively on which children require overnight monitoring. Those children who are off oxygen 2–3 hours following surgery and have passed a SRAC are safe for same-day discharge from a respiratory standpoint. Future investigations are necessary not only to confirm these suggestions, but also to ascertain if there is an optimal observation period to determine that the child will not require readmission for poor oral intake. An investigation that provides prophylactic asthma treatment prior to T&A would be helpful, and research on the role of opioids and PRAEs is also necessary. To achieve this goal, further research and standardization of what qualifies as a PRAE is necessary.

CONCLUSION

In conclusion, all children in our study who were off oxygen within 3 hours of surgery and passed a SRAC were safe for discharge from a respiratory standpoint regardless of age, obesity status, asthma diagnosis, and OAHI. Additional investigations are necessary to confirm our findings and one should still perform their T&As at facilities where there is an option to monitor overnight if needed.

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