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ORIGINAL ARTICLE

Perioperative respiratory complications following awake and deep extubation in children undergoing adenotonsillectomy

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Summary

Background: Perioperative respiratory complications after adenotonsillectomy (T&A) are common and have been described to occur more frequently in children below 3 years of age, those with cranio-facial abnormalities, Down syndrome, obstructive sleep apnea, morbid obesity, and failure to thrive.
Aims: To investigate the association between awake vs deep tracheal extubation and perioperative respiratory conditions.
Results: The primary outcome was any perioperative respiratory complication. Major complications included the need for airway reinstrumentation, continuous or bi-level positive airway pressure (CPAP or BiPAP) and ventilation, or pharmacologic intervention for managing airway obstruction. Minor respiratory complications included persistent hypoxemia defined as oxygen saturation (SpO_2) <92% for ≥30 s or postoperative oxygen dependence for hypoxemia for ≥15 min. There was no statistically significant difference in the incidence of any perioperative respiratory complication in children undergoing an awake vs deep extubation (18.5% and 18.9% for awake and deep extubation, respectively ($P = 0.93$)). Only low weight (≤14 kg) was associated with increased perioperative respiratory complications ($P = 0.005$). In this study, factors found not to be statistically significant with perioperative respiratory complications included age; presence of Down syndrome, cranio-facial abnormality, or cerebral palsy; obstructive sleep apnea confirmed by polysomnography; diagnosis of obstructive sleep apnea by clinical history; presence of an upper respiratory tract infection (URI) within 2 weeks of presentation; history of reactive airway disease; status at extubation; endtidal sevoflurane and carbon dioxide concentrations at extubation; total intraoperative opioids administered in morphine equivalents ($mg \cdot kg^{-1}$); administration of propofol at extubation; and intraoperative administration of an anticholinergic drug.
Conclusions: There was no difference in the incidence of perioperative respiratory complications in children undergoing a T&A following an awake vs deep extubation. Only weight ≤14 kg was associated with increased perioperative respiratory complications.

Background

Adenotonsillectomy (T&A) is one of the most common surgical procedures performed in children and is indicated for obstructive sleep apnea (OSA), sleep-disordered breathing, and recurrent tonsillitis or pharyngitis. Perioperative respiratory complications are common after a T&A, with a higher risk noted in children

<3 years of age, children with cranio-facial abnormalities, Down syndrome, documented severe obstructive sleep apnea by polysomnography, morbid obesity, and failure to thrive (1). These perioperative respiratory complications may be defined as major or minor respiratory complications (2). Major respiratory complications have been reported to occur in 5–20% of children after a T&A and are defined as airway obstruction requiring intervention with a supraglottic airway, positive-pressure ventilation with continuous or bi-level positive airway pressure (CPAP or BiPAP), tracheal reintubation, or pharmacologic intervention (e.g., succinylcholine, naloxone, and flumazenil). Minor respiratory complications have been reported to occur in 10–30% of children and include hypoxemia and oxygen dependence secondary to hypoxemia (3–6). The timing of tracheal extubation after a T&A remains controversial with two different extubation techniques commonly performed: extubation with the child awake or deeply (deep) anesthetized. Advocates of each technique debate their relative advantages and disadvantages. Awake extubation entails removal of the endotracheal tube after return of laryngeal and pharyngeal reflexes, eye opening, grimacing, coughing, and purposeful movements. This technique assures protection from aspiration and airway obstruction with return of laryngeal reflexes, but may be associated with coughing and bucking, potentially increasing the risk of postoperative bleeding, wound dehiscence, and decreased oxygen saturation (SpO_2). Tracheal extubation with the child deeply anesthetized, or 'deep extubation', before the return of laryngeal reflexes removes the strong stimulus by the endotracheal tube for coughing during extubation, but leaves the patient with an unprotected airway, potentially increasing the risk of aspiration and airway obstruction (7). Proponents of deep extubation state the technique also reduces the time from the end of surgery to the start of the following case. It is unknown if efficiencies in throughput of patients in the operating rooms after deep extubation are offset by increased use of nursing resources in the post anesthetic care unit (PACU) and decreased PACU stays. Practices differ between institutions and between practitioners within the same institution, and a few anesthesiologists extubate a child deep but wait until the return of airway reflexes before transporting the child to the PACU. There are only a few randomized studies comparing the incidence of perioperative respiratory complications following awake and deep extubation (7–10). Some of these studies are not relevant to current practice, as the patients received older anesthetic agents no longer used (e.g., halothane) (7,8). This observational study compared the incidence of perioperative respiratory complications in children undergoing a T&A following awake and deep extubation with the use of newer anesthetic agents such as sevoflurane and propofol.

Methods

All children presenting for a T&A between September 2011 and December 2011 at Texas Children's Hospital were eligible for this observational study. The Institutional Review Board of the Baylor College of Medicine approved the study to be performed without written consent, as there was no randomization, no experimental intervention, and no change in anesthetic management, with each attending anesthesiologist responsible for selecting the anesthetic and extubation technique.

Prospective data collection included preoperative, intraoperative, and postoperative information, which was voluntarily reported by each attending anesthesiologist and PACU nurse, on a data collection sheet prior to the advent of an electronic anesthetic medical record at our institution. Preoperative information gathered included age, weight, OSA confirmed by polysomnography, presence of OSA by clinical history, history of Down syndrome, cranio-facial abnormality, or cerebral palsy, presence of an URI within 2 weeks of presentation, and history of reactive airway disease. Intraoperative information gathered included extubation technique, either awake or deep, endtidal sevoflurane and carbon dioxide concentrations (Et sevoflurane % and $EtCO_2$ mmHg) at extubation, total intraoperative opioids administered in morphine equivalents ($mg \cdot kg^{-1}$), administration of propofol within 5 min of extubation, and intraoperative administration of an anticholinergic drug during the procedure. The choice of drugs and timing of tracheal extubation was determined by the clinical judgment of the attending anesthesiologist and was not altered for the study. All patients received inhalation anesthetics and opioids. No specific criteria were provided to the attending anesthesiologist for awake or deep extubation, and the assessment of whether the extubation was awake or deep was determined by the attending anesthesiologist.

Perioperative respiratory complications were defined as either major or minor (3–6). A major respiratory complication was defined as the need for continuous or bi-level positive airway pressure (CPAP or BiPAP) >1 min, need for a jaw thrust >1 min, need for airway instrumentation, or a need for pharmacologic administration (e.g., succinylcholine, naloxone, and flumazenil) to manage airway obstruction. A minor respiratory complication was defined as a SpO_2 <92% for more than 30 s and postoperative oxygen dependence for more than 15 min to maintain a SpO_2 >92%. Perioperative complications were further divided into intraoperative (OR) and postoperative (PACU) complications depending on the location of the child when the complication occurred. The primary outcome was the incidence of any perioperative respiratory complication.

Statistics

The incidence of any perioperative respiratory complication following awake and deep extubation was estimated and further classified into major or minor complications based on the criteria noted above (3–6). The primary outcome was the occurrence of any perioperative respiratory complication. Interval data was categorized, and predictor variables were summarized by frequencies with percentages. Summary statistics were stratified by complication severity [minor, major, and any (major or minor)] as well as location (OR, PACU, or any). Fisher's exact test, used for univariate comparisons and statistical significance, was assessed at the 0.10 level. Three independent multiple logistic regression models were used to estimate multivariable associations between predictors and complications in the OR, PACU, and either location. Only the variables significant at the 0.10 level in the univariate analysis were considered in the multiple logistic regression models. The final model included only variables significant at the 0.05 level after simultaneously adjusting for other covariates and the child's anesthetic status at tracheal extubation (awake vs deep). Measures of association are summarized by adjusted odds ratios with 95% confidence intervals. As many of the predictor variables had highly skewed distributions, interval predictor variables were categorized for analysis and summarized by frequencies with percentages. Categories were first defined by quintiles and then reduced based on Wald chi-square test results as well as model fit statistics such as Pearson's chi-square test, Aikaike's information criteria, and Bayes information criteria. This included categorizing patient weight into a group ≤14 kg and another group >14 kg. The cutoff point represented the first quartile, and the grouping was based on model fit statistics and pairwise comparisons.

Results

Nine hundred and five children underwent a T&A at Texas Children's Hospital during the study period. Completed data for 880 children undergoing a T&A were reported by the attending anesthesiologist. Tracheal extubation was performed with the child deeply ('deep') anesthetized in 577 (66.6%) children, and with the child awake in 303 (33.4%) children (Figure 1). The preoperative demographics and intraoperative characteristics for children undergoing awake and deep extubation are noted in Table 1. As expected, children undergoing an awake extubation had lower endtidal sevoflurane and carbon dioxide concentrations at extubation. This group of children was also statistically more likely to have OSA confirmed by polysomnography and receive lower doses of intraoperative opioids in

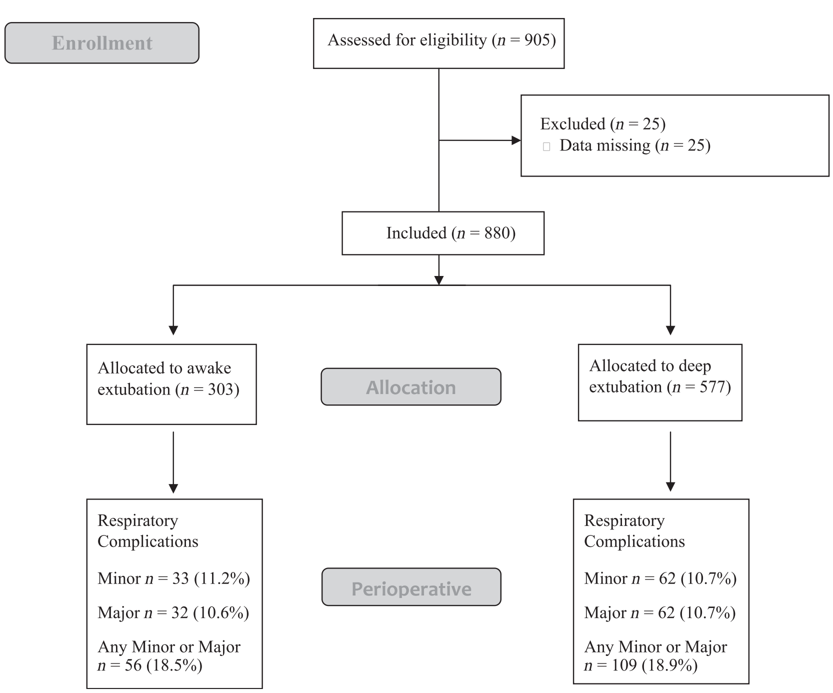

Figure 1 CONSORT patient flow diagram.

Table 1 Preoperative demographics and intraoperative characteristics

	Extubation technique		
	Awake (n = 303)	Deep (n = 577)	P-value
Preoperative			
Age (years)			
Median	5.0 (Min: 1.00, Max: 17.00)	4.0 (Min:1.00, Max:19 .00)	0.57
1–3 years	113/302 (37%)	236/575 (41%)	
4–6 years	74/302 (25%)	134/575 (23%)	
6 + years	115/302 (38%)	204/575 (35%)	
Weight (kg)			
Median	19.4 (Min:6.00, Max:157.00)	18.56 (Min:6.7, Max:99.5)	0.36
6–14 kg	77/299 (26%)	141/572 (24%)	
14.1–18.6 kg	67/299 (22%)	147/572 (26%)	
18.7–26.9 kg	70/299 (23%)	149/572 (26%)	
>27 kg	85/299 (28%)	136/572 (24%)	
Number with OSA by polysomnography (%)	52/303 (17%)	64/576 (11%)	0.02
Number with OSA by history (%)	173/303 (57%)	30/576 (52%)	0.18
Number with syndrome or genetic disorder/cranio-facial abnormality/cerebral palsy (%)	13/303 (4%)	16/576 (2%)	0.24
Number of patients with URI (%)	42/303 (13%)	113/576 (19%)	0.04
Number of patients with reactive airway disease (%)	53/303 (17%)	110/576 (19%)	0.58
Intraoperative			
Endtidal sevoflurane concentration at tracheal extubation (%)			
Median	0.3 (Min:0.0, Max:2.9)	2.0 (Min:0.0, Max:6.70)	<0.01
<1%	242/253 (96%)	166/545 (30%)	
1–2%	8/253 (3%)	120/545 (22%)	
>2%	3/253 (1%)	259/545 (48%)	
Endtidal CO_2 concentration at tracheal extubation (mmHg)			
Median	48.0 (Min:14.0, Max:66.0)	50.0 (Min:0.0, Max:70.0)	<0.01
<45 mmHg	89/276 (32%)	189/547 (32%)	
45–55 mmHg	159/276 (58%)	159/547 (58%)	
>55 mmHg	28/276 (10%)	28/547 (10%)	
Opioid dose in morphine equivalents (mg·kg^{-1})			
Median	0.09 (Min:0.00, Max:0.26)	0.11 (Min:0.00, Max: 0.31)	<0.01
Number of subjects receiving propofol (%)	64/303 (21%)	127/577 (22%)	0.73
Number of subjects receiving anticholinergic drugs (%)	138/303 (45%)	275/573 (48%)	0.47

morphine equivalent units (mg·kg^{-1}) (Table 1). Children undergoing a deep extubation were statistically more likely to have an upper respiratory tract infection (URI).

There was no statistical difference in the incidence of perioperative respiratory complications between the awake and deep extubation groups (Table 2, Figure 1). The incidence of minor, major, and any perioperative complications following awake extubation were 11.2%, 10.6%, and 18.5%, respectively, compared to 10.7%, 10.7%, and 18.9%, respectively, for deep extubation. Some children only had a major or minor complication in one setting, whereas others had a major and minor complication both intraoperatively and postoperatively. Hence, the incidence of any perioperative complication was not the sum of the incidences of intraoperative and postoperative complications or the sum of major or minor complications.

There were 13 (1.5%) unplanned admissions, with extubation performed awake in six children and deep in seven children. An unplanned ICU admission occurred in a single child (0.1%); this patient was 2 years of age and required postoperative mechanical ventilation following deep extubation.

In the univariate analysis, factors associated with the occurrence of any intraoperative (OR) respiratory complications included URI during the previous 2 weeks, total intraoperative opioids administration of $\geq$0.1 mg·kg^{-1} morphine equivalents, and a weight $\leq$14.0 kg. In the multiple logistic regression model, adjusting for anesthetic status at extubation, URI and total morphine equivalents maintained statistically significant associations with any OR respiratory complication. The odds

Table 2 The Incidence of Intraoperative, postoperative, and any perioperative respiratory complications following awake and deep extubation

	Extubation technique		
	Awake (n = 303)	Deep (n = 577)	P-value
Intraoperative			
Minor	9 (3.0%)	9 (1.6%)	0.21
Major	19 (6.3%)	33 (5.8%)	0.76
Any minor or major	23 (7.6%)	34 (9.9%)	0.39
Postoperative			
Minor	34 (11.2%)	52 (9.0%)	0.73
Major	16 (5.3%)	28 (4.9%)	1.00
Any minor or major	48 (15.8%)	75 (13.0%)	0.76
Perioperative (either intraoperative or postoperative)*,**			
Minor	33 (11.2%)	62 (10.7%)	0.82
Major	32 (10.6%)	62 (10.7%)	1.00
Any minor or major	56 (18.5%)	109 (18.9%)	0.93

*Any perioperative complication is not the sum of major or minor complications, as some patients had more than one type of complication.

**Any perioperative complication is additionally not the sum of intraoperative or postoperative complications, as some patient only had a complication in one setting.

of any intraoperative respiratory complication was greater among patients with URI compared to those without URI (Odds Ratio = 2.1, 95% CI: 1.2, 4.0), and in children who received total intraoperative opioids in a morphine equivalent dose exceeding 0.1 mg·kg^{-1} (Odds Ratio = 0.4, 95% CI 0.2, 0.8). Extubation status (awake or deep) was not significantly associated with any intraoperative complication (Odds Ratio = 1.2, 95% CI: 0.7, 2.1) (Table 3). A weight ≤14 kg was no longer significantly associated with intraoperative (OR) complications (P = 0.18) after adjusting for extubation status, URI, and total intraoperative opioid morphine equivalents.

Weight ≤14 kg; children with Down syndrome, a cranio-facial abnormality, or cerebral palsy; a history of RAD, an $EtCO_2$ concentration >55 mmHg at extubation, and any OR complication were significantly associated with minor postoperative (PACU) respiratory complications in the univariate analysis. Only a history of reactive airway disease was associated with major PACU complications. Weight ≤14 kg; children with Down syndrome, a cranio-facial abnormality, or cerebral palsy; and any intraoperative respiratory complication were also associated with any PACU complication in the univariate analysis. Adjusting for extubation status in the multivariate model, weight ≤14 kg (Odds Ratio = 1.9, 95% CI: 1.2, 2.8), children with Down syndrome, a cranio-facial abnormality, or cerebral palsy (Odds Ratio = 3.0, 95% CI: 1.3, 6.9) and any intraoperative complication (Odds Ratio = 2.6, 95% CI: 1.4, 4.8) were more likely to have PACU complications. Extubation status (awake vs deep) was not significantly associated with any PACU complication (Odds Ratio = 1.0, 95% CI: 0.7, 1.5) (Table 3).

Weight ≤14 kg was significantly associated with any perioperative complication whereas children with Down syndrome, a cranio-facial abnormality, or cerebral palsy and higher $EtCO_2$ concentration (>55 mg) at extubation were more likely to have any minor perioperative complication. A number of factors had P values >0.1 in the univariate analysis and were not included in the multiple logistic regression analysis for any perioperative respiratory complication. These included age, weight percentile, OSA by clinical history or polysomnography, the endtidal sevoflurane concentration at extubation, and the use of propofol at extubation and administration of

Table 3 Multiple logistic regression model results for intraoperative, postoperative (PACU), and any perioperative complications

Adjusted odds ratio estimates	Adjusted odds ratio estimates	95% confidence interval		P-value
Intraoperative (OR)				
Anesthetic status at extubation (awake vs deep)	1.2	0.7	2.1	0.48
URI	2.1	1.2	4.0	0.02
Morphine equivalents ≤0.1 mg·kg^{-1}	0.4	0.2	0.8	0.004
Postoperative (PACU)				
Anesthetic status at extubation (awake vs deep)	1.0	0.7	1.5	0.97
Weight (≤14 vs >14 kg)	1.9	1.2	2.8	0.003
Down syndrome/cranio-facial abnormality/cerebral palsy	3.0	1.3	6.9	0.009
OR complication	2.6	1.4	4.8	0.003
Perioperative				
Anesthetic status at extubation (awake vs deep)	1.0	0.7	1.4	0.78
Weight (≤14 vs >14 kg)	1.7	1.2	2.5	0.005

an anticholinergic drug during the procedure. After adjusting for extubation status, only lower weight (≤14 kg) was significantly associated with having any perioperative complication (Odds Ratio = 1.7, 95% CI: 1.2, 2.5). Extubation status (awake vs deep) was not associated with any perioperative complication (Odds Ratio = 1.0, 95% CI: 0.7, 1.4) (Table 3).

Discussion

This observational study of 880 children undergoing a T & A did not reveal differences in perioperative respiratory complications in those extubated awake vs deeply anesthetized. The incidence of minor and major respiratory complications following a T&A has been reported to range from 10% to 30% and 5% to 20%, respectively (1–6,9,10). Two older studies have assessed the incidence of perioperative respiratory complications following awake and deep extubation in children undergoing a T&A (7,8). Patel *et al.* (7) found no difference in the incidence of perioperative respiratory complications, including oxygen saturation levels, croup, excessive coughing, and laryngospasm in seventy children. Although the children were randomized into an awake or deep extubation group, the anesthetic technique was standardized for only the endtidal halothane concentration at extubation. There was no power analysis in this study, leading to the possibility of a type 2 error in the conclusions. In another study, von Ungern-Sternberg *et al.* randomized 100 children at high risk for respiratory complications following an adenotonsillectomy into an awake or deep extubation group. This study was designed with an 80% power to detect an assumed difference in respiratory complications of 35% in those extubated awake and 10% in the deep group. This would result in a calculated absolute difference of 25%. The basis for the power analysis assumptions was not provided in this report (10). The investigators found no difference in hypoxemia or laryngospasm but reported an increased incidence of persistent coughing following an awake extubation and airway obstruction relieved by simple airway maneuvers following a deep extubation (10). Although the extubation technique was not standardized, deep extubation was defined as an endtidal sevoflurane concentration >1 minimum alveolar concentration. We did not have a restrictive definition for deep extubation as there is no standard definition or methodology for deep extubation (9).

Awake extubation following a T&A is advised as the standard technique in some institutions given the concern for postoperative airway obstruction and respiratory complications. Many anesthesiologists recommend awake extubation for children who are at increased risk of aspiration of gastric contents, those children with a difficult airway, or those children with a history of OSA or sleep-disordered breathing. It is possible that subjects sent for polysomnography have more severe OSA than those who present with a clinical history suggestive of OSA. This is in keeping with our institutional practice as shown by the fact that children extubated awake had a higher proportion of OSA confirmed by polysomnography than by clinical history. However, we did not demonstrate any difference in the incidence of perioperative complication following awake or deep extubation even in the 116 high-risk children with OSA confirmed by polysomnography. This may reflect a clinical practice where all children were cared for by experienced pediatric anesthesiologists and pediatric PACU nurses in a tertiary children's hospital. It may also reflect a study design where the selected extubation technique was based on the clinical judgment, expertise, and comfort of the attending anesthesiologist. Unlike the study by von Ungern-Sternberg *et al.*, our study was not a randomized controlled trial and so does have a limitation in possible selection bias toward one extubation technique, particularly in high-risk children with obstructive sleep apnea confirmed by polysomnography. However, many children with obstructive sleep apnea are not diagnosed by polysomnography but by clinical history given the scheduling difficulty and costs of obtaining an overnight polysomnography (11). Our study failed to show significant differences in respiratory complications after awake or deep extubation in children diagnosed with OSA by either polysomnography or clinical history.

This study has other limitations including the lack of a standardized anesthetic technique. All patients received an inhalational-based anesthetic with intraoperative opioids where the type and dose of the opioid were at the discretion of the attending anesthesiologist. In keeping with other studies, the opioid dose was converted to morphine equivalent units ($mg \cdot kg^{-1}$) for statistical analysis. However, we did not provide specific criteria or defined procedures for awake or deep extubation, as there is no standard definition or procedure for awake or deep extubation, and there are many variations in suctioning, oxygenation, patient positioning, and airway management during this critical event (9,10,12). The assessment of whether extubation of the trachea was performed with the child awake or deeply anesthetized was determined by the attending anesthesiologist. We specifically did not wish to restrict the practice of 40 practitioners to a single protocol given the large variability in our practice. The results of a standardized extubation technique by protocol in randomized clinical trials would be limited to that technique and could not be generalized to a broader comparison of airway complications between the two extubation techniques (7–10).

The incidence of perioperative respiratory complications may be influenced by the experience of the attending anesthesiologist and the presence of trainees. Our clinical practice includes approximately 40 attending anesthesiologists with fellowship training in pediatric anesthesia but with different years of experience. Trainees, including student nurse anesthetists, anesthesiology residents, and pediatric anesthesiology fellows, were involved in approximately half of these cases per our institutional practice, and the remaining cases received direct care by a pediatric anesthesiologist. However, all trainees and certified nurse anesthetists were closely supervised by the attending anesthesiologist, who was always present at induction and emergence, while also being immediately available at all times and was not assigned to provide care for more than one operating room per our institutional practice. We believe the respiratory complications cannot be attributed solely to trainee inexperience.

The experience and comfort level of the PACU nurses can be an additional factor in the choice of the extubation technique. All 30 PACU nurses at our institution had experience in managing airway complications in children, although the number of years of pediatric clinical experience did vary. The PACU nursing ratio is 1 nurse per 2 patients with occasional cross-coverage depending upon the patient census. The availability and experience of the nurse may have been responsible for early intervention preventing a minor respiratory complication from becoming a major respiratory complication. It is possible that the results may be different under other PACU nursing conditions (e.g., where nurses take care of both adults and children). Some other institutions additionally assign an anesthesiologist to be always available in the PACU to address complications.

The incidence of respiratory complications can also be affected by perioperative drug use. Children with a history of OSA have an increased sensitivity to the respiratory depressant effects of opioids and should receive lower doses (4,11). In our study, children who received <0.10 $mg \cdot kg^{-1}$ morphine equivalents had a lower incidence of intraoperative complications in the multiple logistic regression analysis, adjusted for extubation status. However, the dose of intraoperative opioids was not an independent factor for increased postoperative or perioperative respiratory complications. In our study, the only independent factor in the multiple logistic regression analysis with a significant association for any perioperative respiratory complications was lower weight (≤14 kg). Children with obstructive sleep apnea may have failure to thrive (weight < 3% percentile) secondary to increased caloric expenditure caused by increased work of breathing during sleep and have been shown to be at increased risk for perioperative respiratory complications (13,14). It is possible that the finding that patient weight below 14 kg was an independent factor for respiratory complications may reflect an interaction between age and failure to thrive. However, the incidence of respiratory complications was not higher in children with a weight below the third percentile. We did not record the height of the children and so cannot calculate the body mass index.

The strength of this study lies in the inclusion of a large number of children with similar demographics, and this reduces the potential impact of confounding factors in a smaller cohort. It did have the additional limitation that all collected variables were self-reported by the attending anesthesiologists and the PACU nurses on a paper form. The incidence of perioperative respiratory complications may have been underreported, but the incidence of both major and minor respiratory complications is similar to what has been previously reported in the literature. While electronic records may be more accurate than manual records, they cannot differentiate artifacts from true events without confirmation by the anesthesiologist (15,16).

Conclusion

In conclusion, our results in a large patient group demonstrated that there is no difference in the incidence of perioperative respiratory complications in children undergoing awake or deep extubation following a T&A.

Ethics

There was no necessary ethics approval for this study.

Acknowledgment

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Conflict of interest

No conflicts of interest declared.

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