Pediatric Anesthesia

Pediatric Anesthesia ISSN 1155-5645

OUTCOMES: REVIEW ARTICLE

Outcome, risk, and error and the child with obstructive sleep apnea

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Keywords
pediatric; obstructive sleep apnea; adenotonsillectomy; respiration; anesthesia

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Section Editor: Charles Cote

Accepted 27 March 2011

doi:10.1111/j.1460-9592.2011.03597.x

Summary

Adenotonsillectomy is the mainstay of treatment for pediatric obstructive sleep apnea syndrome (OSAS). However, there is evidence that the child with severe OSAS is at increased risk of respiratory compromise. The most difficult risk factor to assess is the severity of OSAS, and these difficulties are reviewed.

Introduction

In 1976, Guilleminault reported sleep apnea in eight children (1). The sleep disturbance in the pediatric obstructive sleep apnea syndrome (OSAS) is characterized by loud snoring, episodic hemoglobin desaturation, hypercapnia, and repeated arousals from sleep. Sleep-disordered breathing may lead to a spectrum of symptoms including neurocognitive and behavioral disturbances, poor school performance, cardiovascular dysfunction, and pulmonary disease (2–5). Whereas, primary benign snoring occurs in 5–27% of children and pediatric OSAS affects only 1–3% (3,6). Pediatric OSAS is as prevalent as childhood asthma. This article discusses Outcome, Risk, and Error in the perioperative management of the child with the severe obstructive sleep apnea who is to undergo tonsillectomy with or without adenoidectomy (abbreviated T&A). The focus is on respiratory morbidity.

Adenotonsillar hypertrophy is a major factor in the development of obstructive breathing during sleep in children, and therefore, T&A is the mainstay of the treatment for OSAS (3), exhibiting a bimodal age distribution with peaks at 5–8 and 17–21 years (7). There has been a resurgence in the rate of T&A. (Figure 1) Adenotonsillectomy represents the most frequently performed ambulatory pediatric surgery in the United States (7). For the year 2005, the American National Health Statistics reported that 530 000 ambulatory T&As were performed in children (under 15 years) in American ambulatory programs including hospitals and freestanding ambulatory surgery centers (8).

Erickson *et al*. examined trends for T&A registered in the Rochester Epidemiology Project database of Olmsted County, Minnesota. Whereas in 1970, the indication for T&A in the majority (88%) was infection, today, the majority indication is pharyngeal obstruction (77%) (Figure 2) (7). (Concordance between the surgical indication reported from the electronic search and a chart review was 91%, in a randomly selected subset of 5%). Worldwide, however, there seem to be important differences. The National Prospective Tonsillectomy Audit of practice in the United Kingdom (https://www.tonsil-audit.org/documents/ta_finalreport.pdf) reported that the indication for T&A in only 10% of patients was pharyngeal obstruction /obstructive sleep

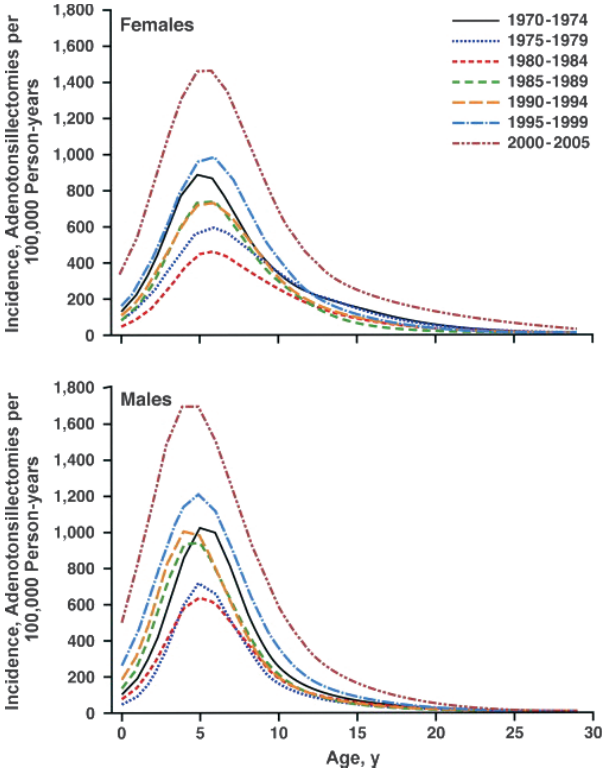

Figure 1 The rate of adenotonillectomy (T&A), normalized to 100 000 person years, in Olmsted County, Minnesota, USA between 1970 and 2005. The nadir surgery occurred 1980–1984, but in the 1990s there has been a resurgence in the rate of T&A. Reproduced with permission from Erickson *et al.* (7).

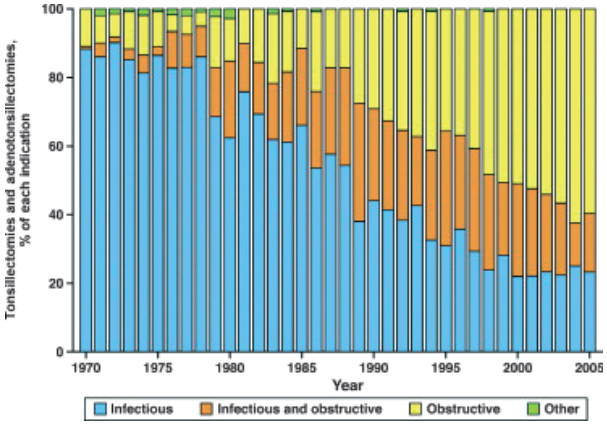

Figure 2 Surgical indications for adenotonsillectomy (T&A) in Olmsted County, Minnesota, USA between 1970 and 2005. Reproduced with permission from Erickson *et al.* (7).

apnea in 2003/2004. Furthermore, in young children (< 5 years), only a third reported pharyngeal obstruction as the indication for T&A (9). As discussed below, the risk of post-T&A respiratory morbidity is higher if the surgical indication is OSAS. Thus global differences in the surgical indication for T&A may underlie regional differences in perioperative morbidity.

Outcome

Deficiencies, highlighted in 1979 by Pratt and Gallagher (10), in the reporting of complications following T&A, have limited accurate reporting of outcomes. Even today, centralized reporting of patients readmitted after discharge from outpatient facilities may not be available, and therefore, statistics relating to postoperative complications are lacking (11). In a recent report of lethal post-tonsillectomy hemorrhage from Germany (12), the method for retrieval of subjects was voluntary reporting.

An estimate of mortality following T&A is 0.6 per 10 000 (12). Although lethal hemorrhage following T&A occurs, less than one-third of tonsillectomy mortality is attributed to bleeding (12,13). The Medical Liability Mutual Insurance Company in New York State reported 36 court trials for malpractice claims of death/major brain injury following T&A, between 1985 and 2007 (13). Nineteen subjects (53%) of death/major brain injury were because of airway complications and postoperative airway events accounted for the majority (60%) of death/major brain injury in children. Compared with adults, children had a twofold higher incidence of fatal respiratory events in the postoperative period following T&A (Table 1). Common postoperative airway complications included airway obstruction and respiratory arrest of unclear etiology. Court trials represent a minority of malpractice claims, and therefore, data should be interpreted cautiously. Nonetheless, it would seem that an additional factor is acting on children to increase the risk of respiratory mortality in the postoperative period. A discussion of risk fac-

Table 1 Frequency of death or profound brain injury from airway and bleeding complications following adenotonsillectomy (T&A). Modified with permission from Morris *et al.* (13)

	Death/brain injury (%)
Children (n = 25)	
Airway (intraoperative)	4 (16)
Airway (postoperative)	11 (44)
Post-T&A hemorrhage	8 (32)
Adult (n = 11)	
Airway (intraoperative)	2 (18)
Airway (postoperative)	2 (18)
Post-T&A hemorrhage	4 (36)

tors for respiratory complications following T&A is warranted.

Risk of post-T&A respiratory complications

Obstructive sleep apnea syndrome

There is overwhelming evidence that children with OSAS have a higher incidence of postoperative respiratory complications including post-obstructive pulmonary edema, pneumonia, airway obstruction, and respiratory failure (14–20). There is very strong evidence that the *severity* of the sleep apnea is an important determinant of this risk. Clinicians become more adept in the identification of the at-risk child if an assessment of OSAS severity is available.

The gold standard for determining OSAS severity requires an assessment of obstructive breathing during sleep with either the apnea hypopnea index (AHI) or respiratory disturbance index (RDI). In children, an AHI that exceeds one event per hour sleep is abnormal (5), but in children with OSAS, the AHI may range from 1 to over 100 events per hour. It is an AHI threshold value above 10 events per hour that has been linked to the risk of respiratory complications following T&A (14,15,17–21). Children with severe OSAS also exhibit hypoxemia during the sleep-related obstructive apnea and hypopnea. Profound recurrent hypoxemia during sleep, below a threshold value of 80%, increases the risk of major medical interventions following T&A (14,17–20).

The predictive value of nocturnal oximetry has been evaluated with likelihood ratios, the ratio of true positives and false positives, and a likelihood ratio above 10 indicates a conclusive change from the pretest to posttest probability of disease (22). Brouillette *et al.* determined likelihood ratios for the oximetry trend graphs and the probability that an abnormal study would be associated with polysomnographic evidence of OSAS (AHI > 1 event per hour) (23). They determined the likelihood ratio for otherwise healthy children (n = 165) with only adenotonsillar hypertrophy as the explanation of their sleep-disordered breathing. An abnormal oximetry trend graph had a likelihood ratio of 43, and a negative/inconclusive result had a likelihood ratio of 0.6. In the population referred to the sleep laboratory, the pretest probability of OSAS was high (64%), and the high likelihood ratio of 43 gave a 99% posttest probability of having OSAS (Figure 3).

Nixon *et al*. extended this work to develop an OSAS severity score, the McGill Oximetry Score (MOS) (19). An abnormal oximetry trend graph was defined as one with ≥3 clusters of desaturation. Three levels of severity (MOS2, MOS3, and MOS4) were identified from the nadir saturation in at least three clusters: <90%, <85%, and <80%, respectively (Figure 4). There are some important take-home messages arising from centers using nocturnal oximetry to assess sleep-disordered breathing which may be relevant to clinicians.

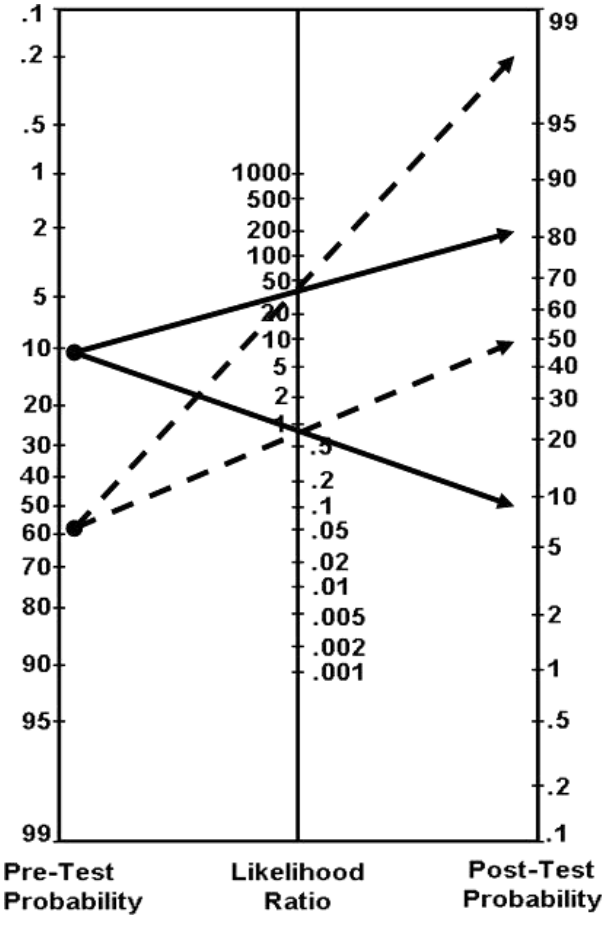

Figure 3 Normogram showing the Pre-Test probability, likelihood ratios, and Post-Test probabilities for pulse oximetry trend studies predicting obstructive sleep apnea syndrome (positive) or not (negative). In otherwise healthy children a positive pulse oximetry trend graph has a likelihood ratio of 43 and a negative pulse oximetry trend graph had a likelihood ratio of 0.6. The Post-Test probability predicting obstructive sleep apnea high, 60%, (—) and low, 10%, (—) Pre-Test probabilities are shown. See text for further explanation. Adapted from Brouillette *et al.* (23).

(1) In populations of otherwise healthy children, with only adenotonsillar hypertrophy as the explanation of their sleep-disordered breathing, a high pretest probability of having OSAS combined with the high likelihood ratio of 43 yields a probability that an abnormal oximetry trend graph is

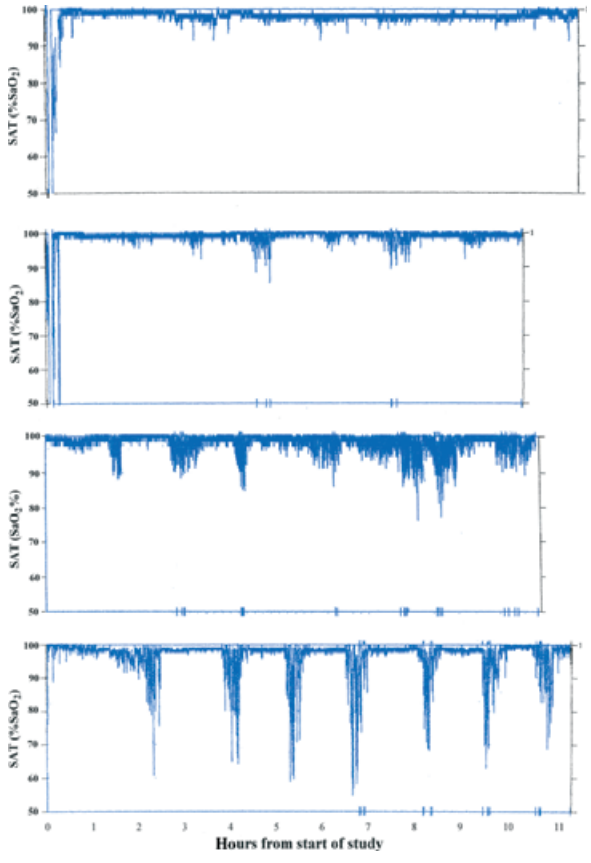

Figure 4 Examples of the oxygen saturation trend graphs from overnight oximetry tests used to develop the McGill Oximetry Score (MOS): from top to bottom, MOS1, MOS2, MOS3 and MOS4. Reproduced with permission from Nixon *et al.* (19) and from Hannallah RS, Brown KA, Verghese ST. Otorhinolaryngologic Procedures. In: Coté CJ, Lerman J, Todres ID, eds. *A practice of anesthesia for infants and children*, 4th edn. Philadelphia, PA: Saunders, 2009:657–683.

associated with OSAS of 99%. In our sleep laboratory, these children require no additional testing to establish the diagnosis of OSAS (19).

(2) The nomogram provided in Figure 3 can be used to estimate the posttest probability of having OSAS for any surgical population of otherwise healthy children for any pretest value. In surgical practices with a high incidence of OSAS, i.e., 77%, the likelihood ratio of 43, means that an abnormal oximetry trend graph yields a posttest probability of having OSAS of 100%. Even in surgical practices with a low incidence of OSAS, i.e., 10%, the high likelihood ratio of 43, means that an abnormal oximetry trend graph has a posttest probability of having OSAS above 80%.

(3) The nadir saturation during sleep is inversely correlated with the AHI (Table 2). We reported that children exhibiting recurrent hypoxemia during sleep (i.e.,MOS2, MOS3, and MOS4) have values for the AHI above 10 events per hour (19). An AHI > 10 is the threshold value predictive of respiratory complications following T&A (15).

(4) The risk of postoperative respiratory complications increases as the severity of preoperative nocturnal hypoxemia worsens (14,17–20) (Table 2).

(5) Children with profound hypoxemia (i.e., nadir saturation < 80% and MOS4) demonstrate a heightened respiratory (24) and analgesic (25,26) sensitivity to opioids (Figure 5). We have linked this heightened analgesic sensitivity to opioids with the report that intermittent hypoxia increases mu-opioid receptor density in piglets (27) and speculate that the molecular process mediating

Table 2 Correlation of the preoperative McGill Oximetry Score (MOS) with the preoperative apnea/ hypopnea index and the post-adenotonsillectomy (T&A) respiratory compromise. Modified with permission from Nixon *et al.* (19)

	Apnea/hypopnea index (events per hour)	Post-T&A respiratory compromise %
MOS2	12.6	35
MOS3	13.3	60
MOS4	39.9	62

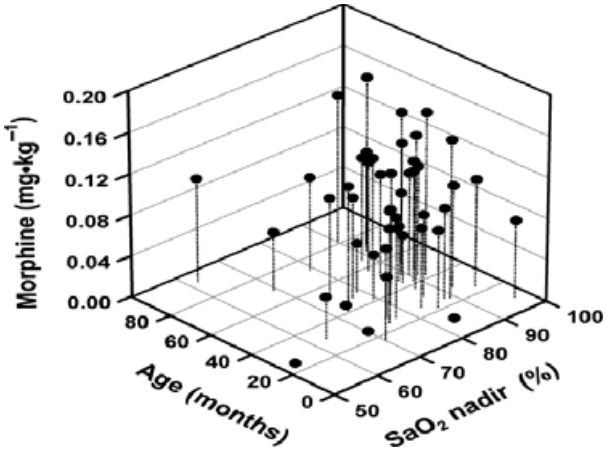

Figure 5 Age (months) and preoperative arterial oxygen saturation (SaO_2) nadir (%) are significantly correlated with the cumulative postoperative morphine dose (mg/kg) required for analgesia after adenotonsillectomy. The correlation of the combined variables with the cumulative postoperative morphine dose is shown. Estimates for each child are depicted with a filled circle. The magnitude of the cumulative postoperative morphine dose in the three-dimensional scatter plot is depicted by the height of the stem supporting each circle. Reproduced with permission from Brown *et al.* (25).

this response involves oxygen-sensitive gene regulation (28). Children living at altitude (chronic hypoxia) also demonstrate a decreased analgesic opioid requirement (29). However, the molecular mechanisms underlying their heightened opioid sensitivity may differ as the stimuli of intermittent and chronic hypoxia illicit distinct physiological and molecular responses (30,31).

(6) The surgical population for T&A exhibits a very high prevalence of hypoxemia during sleep. A third of an unselected surgical population of 44 children with adenotonsillar hypertrophy assessed the night prior to T&A exhibited baseline saturations below 90% and/or episodic hypoxemia during sleep (32). The incidence of recurrent hypoxia during sleep in a surgical population of 334 children referred for preoperative evaluation of sleep-disordered breathing was 30% (33). In comparison, only 2.4% of an unselected population of German primary school children demonstrated recurrent episodic desaturation during sleep (6).

Ethnicity

Although there is, as yet, no evidence that ethnicity is an independent risk factor for respiratory morbidity following T&A, there is strong evidence that African American ethnicity is a risk factor for OSAS. Sleep-disordered breathing is almost twice as prevalent in young African Americans compared with Caucasians (34) and these children are three times more likely than controls to have OSAS (35). African American children with sleep-disordered breathing report more difficulty with nasal breathing during wakefulness than controls. In addition, African American children with OSAS had significantly lower oxygen saturations during obstructive airway events compared with other ethnicities, and the median (interquartile range) of the nadir saturation during rapid eye movement sleep in African American children was 80% (24,36).

Multisystem disease

Pediatric OSAS is a multisystem disease, and severe OSAS is associated with abnormalities that may of themselves increase the risk for perioperative complications. These pathophysiologies include pulmonary and systemic hypertension, ventricular hypertrophy, and lower airways disease (2,3,16). Alterations in ventilatory control may also be present. Don *et al*. remarked that children with OSAS demonstrate a higher than expected central apnea rate (average 2.5 per hour) and suggested this may reflect abnormalities of ventilatory control (16). Shine *et al*. reported a high incidence of central apnea in obese children with OSAS (21). Children with OSAS demonstrate a blunted responsiveness to carbon dioxide (37). Alterations in ventilatory control may be linked to the heightened respiratory sensitivity to halothane and opioids reported by Waters *et al*. (24).

Age

Young age is an independent risk factor for respiratory complications following T&A (14,15,17). In addition, hypoxemia during sleep-disordered breathing is common in young children. Figure 6 shows that hypoxemia during sleep is more common in young children with OSAS than older children (16). Constantine *et al*. reported that 39% of children with OSAS who were under 3 years had hypoxemia during sleep-disordered breathing and for each 1-year increase in age, the odds of having hypoxemia during sleep decreased by 17% (33).

Medical co-morbidity

The presence of a medical co-morbidity is an independent risk factor for respiratory complications following T&A (14,15,17). This is true regardless of the nature or the number of the co-morbidities be they prematurity, neuromuscular disease, seizure disorder, Down syndrome, craniofacial anomalies, cardiac disease, asthma, or obesity. Because the overall risk is the product, not the sum, of independent risk factors, combinations of young age, medical co-morbidity, and severe OSAS identify a child at high risk of post-T&A respiratory complications. One study found that 7 of 61 (11%) children under 2 years, with medical co-morbidity and severe OSAS, required a major medical

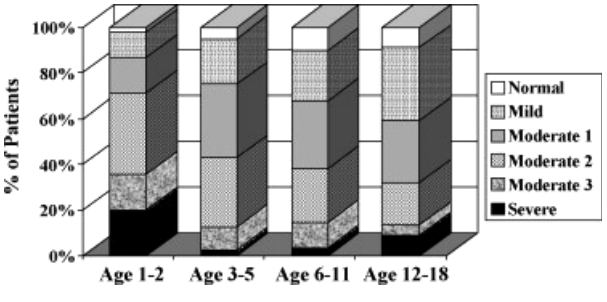

Figure 6 Bar graph representing the percentage of patients by age in the normal, mild, moderate and severe obstructive sleep apnea syndrome categories. Children in the moderate and severe categories demonstrated recurrent episodic hypoxia during sleep. Reproduced with permission from Don *et al*. (16).

intervention for respiratory complications following T&A (38).

Obesity is a medical co-morbidity that deserves special mention as it is both a cause and consequence of OSAS. Both OSAS and obesity are systemic inflammatory diseases, and there is evidence of metabolic disturbances in children when OSAS and obesity coincide (5). The risk of sleep-disordered breathing in obese children increases fourfold (39) and for every BMI increment of 1 kg/m^2, beyond the mean BMI, the risk of OSAS increases 12% (40). The prevalence of severe OSAS in obese children is 46% (41). However, in a retrospective comparison between otherwise healthy obese and non-obese children with polysomnogram (PSG) proven OSAS, there was no evidence for a significant correlation between the degree of obesity and the severity of OSAS (40). Mallampati scores were higher in the obese children. Shine *et al.* (21) reviewed 26 consecutive morbidly obese (BMI > 95th percentile) children (2–17 years) admitted to intensive care following T&A for the treatment of OSAS. Whereas no threshold of RDI was associated with postoperative morbidity, a preoperative sleep study with a saturation nadir below 70% and/or central apnea was associated with respiratory compromise following T&A. The severity of OSAS in obese children can only be determined by preoperative testing.

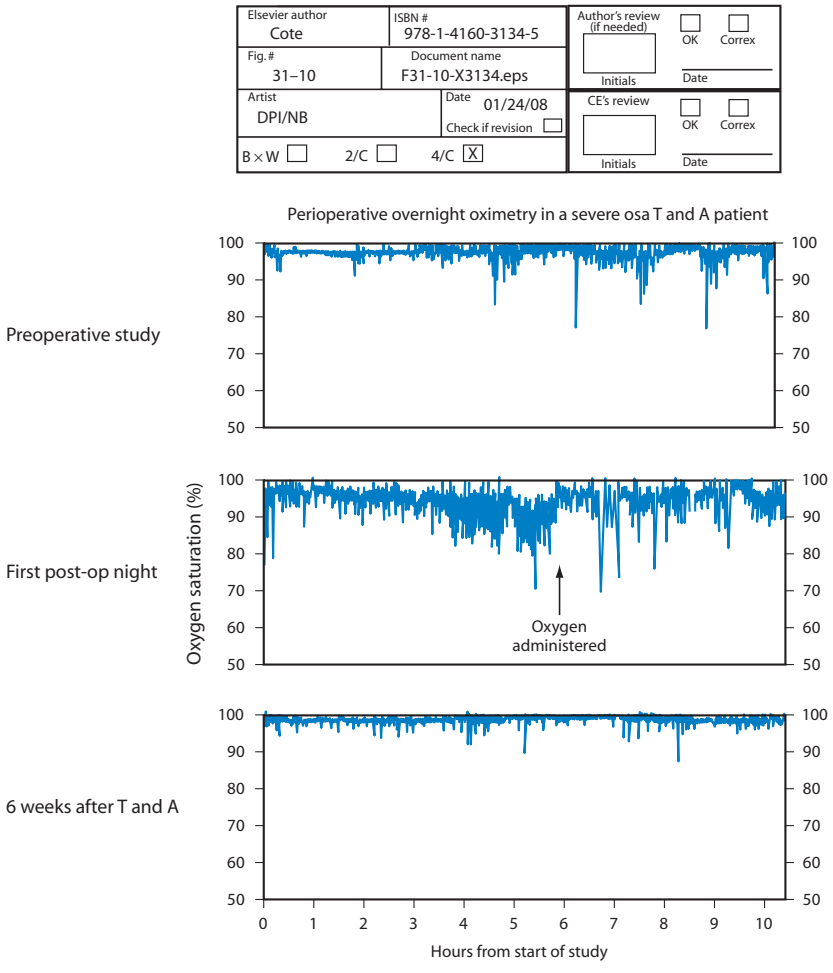

Figure 7 Overnight oximetry trend reports for an otherwise healthy 2.8 year old boy. Clusters of desaturation are seen in the preoperative study, reflecting obstructive events in rapid eye movement sleep. On the first postoperative night, obstructive apneas and hypopneas occurred frequently from sleep onset, leading to repetitive desaturation below 80%. Note administration of supplemental oxygen 12 h after T&A. He was admitted for an additional 2 nights until desaturation during sleep had resolved. Oximetry performed 6 weeks after surgery is within normal limits. Reproduced with permission from Nixon *et al.* (42) and from Hannallah RS, Brown KA, Verghese ST. Otorhinolaryngologic Procedures. In: Coté CJ, Lerman J, Todres ID, eds. *A Practice of Anesthesia for Infants and Children*, 4th edn. Philadelphia, PA: Saunders, 2009:657–683.

Table 3 Parameters [mean (range)] of sleep and breathing on preoperative and first night following adenotonsillectomy in children with the obstructive sleep apnea syndrome (OSAS) by severity of preoperative nocturnal hypoxemia. Modified with permission from Nixon *et al.* (42)

	Severe group (n = 5)	Mild group (n = 5)	P value
Nadir saturation on preoperative overnight oximetry (%)	76 (54–79)	87 (86–91)	0.009
First postoperative Night			
Mixed/obstructive Apnea/hypopnea index (events per hour)	21.5 (15.1–112.1)	6.9 (2.2–9.8)	0.009
Nadir saturation (%)	82.9 (73.5–89.5)	88.0 (81.0–90.0)	0.46
Desaturation events due to obstructive events (%)	99.6 (94.0–99.8)	66.9 (19.9–89.5)	0.02
Longest mixed/obstructive apnea (sec)	24.3 (23.1–27.2)	14.0 (10.8–19.2)	0.05

Residual OSAS

Nixon *et al.* recorded abbreviated cardiorespiratory studies on the night following T&A in otherwise healthy children, with OSAS, who were aged over 2 years,. All children demonstrated obstructive airway events on the first night following T&A (Figure 7). These events were four times more likely in those children with severe nocturnal hypoxemia on the preoperative oximetry trend graph. Virtually, all desaturation events were associated with obstructive events. The duration of the mixed obstructive apnea, recorded on the first night following T&A, exceeded 20 s in the severe group (42) (Table 3).

A multinational retrospective study involving nine pediatric centers reported that whereas two-thirds of children with mild and moderate OSAS show complete resolution of their sleep-disordered breathing six weeks following T&A, one-quarter of children with severe OSAS do not. Residual disease was more likely in older children (>7 years) and in the obese (3). In obese children compared with non-obese children, the odds ratio for persistent OSAS (defined by an RDI $>$ 5) was 4 (43). Indeed Dayyat *et al.* propose 2 types of OSAS disease exist in children, one associated primarily with obesity and the second associated with marked adenotonsillar hypertrophy (5). In non-obese children, asthma and severe OSAS were more likely to be associated with residual disease (3) and a preoperative AHI $>$ 19 events per hour was associated with residual disease (44).

Anesthetic management

There is little published evidence to recommend a specific anesthetic technique for T&A in the child with OSAS. Helfaer *et al.* (45) reported no difference in respiratory outcome between a halothane anesthetic technique and a balanced technique which included fentanyl in a children with mild OSAS (AHI = 5 events per hour). However, in children with severe OSAS, reports of an altered ventilatory control, an increased respiratory sensitivity to halothane, and a heightened opioid sensitivity suggest that these children may be more vulnerable to respiratory depression during anesthesia and recovery. A management strategy individualized to the severity of preoperative hypoxemia reduced the incidence of respiratory complications following T&A in children (46).

Error

Management of OSAS on an outpatient basis

Our criteria for hospitalization following T&A include medical co-morbidity, young age, a bleeding diathesis, disadvantaged social environment, excessive distance from a hospital, excessive pain, poor oral intake, postoperative vomiting, and an awake (room air) saturation below 95%. It is likely that the children represented in Figure 7 and Table 3 would have met the discharge criteria of most outpatient facilities, as these children were awake and taking oral fluids in the afternoon following T&A. However, at least 5 h following surgery, with sleep onset, all children demonstrated obstructive respiratory events on the first night following T&A (42). Any child with a history of severe OSAS, young age, and/or medical co-morbidity must be admitted following T&A and observed in the safety net of the hospital environment.

All children exhibiting hypoxemia on the preoperative sleep study should be monitored with continuous oximetry during sleep following T&A. Helfaer *et al.* concluded that the improvement in saturation and obstructive respiratory events in children with mild OSAS (AHI = 5) did not justify intensive monitoring on the first night following T&A (45). Many advocate elective admission to the intensive care unit for children with severe OSAS (AHI $>$ 10, nadir saturation $<80\%$, carbon dioxide retention) (15,20,21). However, we have reported that when the perioperative management is individualized to the severity OSA, utilization of the intensive care unit for children with severe OSAS decreased (46). Our local practice recommends that post-T&A admission to the intensive care unit be

reserved for children with severe recurrent episodic hypoxia (MOS4) plus young age (< 2years) and/or medical co-morbidity. In the absence of intraoperative complications, our practice is to monitor otherwise healthy children with *severe* recurrent episodic hypoxia (MOS4), overnight in the recovery room with continuous oximetry.

Whereas, young age and medical co-morbidity are easily identifiable risk factors, OSAS is more difficult to diagnose in children. Health care systems with access to pediatric sleep laboratories are able to identify children with severe OSAS and exclude them from ambulatory T&A programs. In the absence of preoperative testing, guidelines published by the American Society of Anesthesiology suggest that clinical criteria may be used to establish a diagnosis of OSAS (2). However, agreement between clinical criteria and the gold standard polysomnography is only 55% (47), and preoperative questionnaires have a sensitivity of only 40% for detecting hypoxemia during sleep (33).

For children aged 1–4 years, the rate of ambulatory anesthesia has increased from 6.2 per 1000 in 1996 to 13.2 per 1000 in 2006 (Figure 8) (11). In this age group, the majority of surgical indications for T&A is likely to have been obstructive breathing, and children in this age group have a high incidence of severe OSAS associated with hypoxemia during sleep (16,33). The average postoperative time prior to discharge from in the recovery room is reported to be 71 min (11), a postoperative observation period which is too short to detect the delayed onset of respiratory compromise reported in children with severe OSAS following T&A (15,16,48). The onus then falls on the anesthesiologist to identify the child with severe OSAS by an unusual response to anesthesia. Premedication may cause excessive snoring, desaturation, and obstructive apnea (49). A difficult mask induction may suggest a high pharyngeal closing pressure (50,51). Excessive respiratory sensitivity to opioids and anesthesia resulting in hypoventilation and apnea may be present (24,52). Children with severe OSAS demonstrate a delayed emergence from anesthesia (18). A persistent oxygen requirement especially during sleep is common in children with severe OSAS following T&A (17–19,42,46).

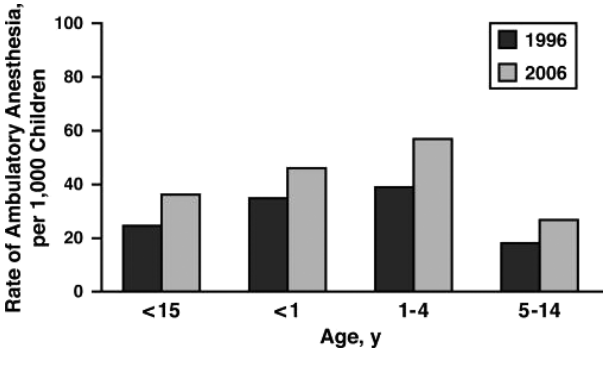

Figure 8 Rate of Ambulatory Anesthesia for children in the United States of America in 1996 and 2006. Rate increased from 26 per 1000 children younger than 15 years in 1996 to 38 per 1000 children of this age group in 2006. Reproduced with permission from Rabbits *et al.* (11).

A system that relies on the behavior during anesthesia and recovery to identify the child with OSAS who should be admitted to hospital is subject to error. Herein lies the potential for nocturnal oximetry as a tool to assess eligibility for ambulatory T&A programs in the preoperative period. An abnormal oximetry trend graph, in otherwise healthy children with adenotonsillar hypertrophy as the explanation for their sleep-disordered breathing, has a very high likelihood ratio for predicting OSAS. Even in populations with a low pretest probability of having OSAS, the posttest probability of having OSAS is high (Figure 3). Furthermore, an abnormal oximetry trend graph stratifies the severity of nocturnal hypoxemia allowing exclusion or the high risk child from ambulatory T&A programs.

Widespread implementation of nocturnal home oximetry evaluation has been slow. For the better part of the twentieth century, the medical elite has questioned the utility of T&A (53) and today, most health care systems define and remunerate specific indications for T&A. This may be a deterrent to preoperative assessment with noctural home oximetry, as surgeons may fear that a negative result would not support the clinical diagnosis of OSAS. However, the likelihood ratio for a negative oximetry trend graph is only 0.6, a value which is not small enough to rule out a diagnosis of OSAS (22).

Conclusion

Data from the Medical Liability Mutual Insurance Company in New York State suggest that compared with adults, children are experiencing a higher incidence of lethal respiratory events in the postoperative period following T&A (13). Overall, the mortality rate for T&A is low, estimated at 0.6 per 10 000 (12), and as the caseload is scattered across hundreds of ambulatory programs, local departmental reviews of morbidity and mortality may not detect trends in respiratory morbidity. Reliable centralized reporting of morbidity and mortality following T&A would be helpful in this regard. With the escalating frequency of OSAS in children undergoing T&A and the obesity epidemic in

children worldwide, perioperative respiratory complications following T&A pose a serious risk to children. Simple non-invasive preoperative diagnostic evaluations are needed to identify at-risk children. Polysomnography cannot fulfill these requirements, and alternative strategies including nocturnal oximetry need to be examined. In addition, further studies are required to develop affordable, accessible, and cost-effective monitoring to identify those children with OSAS who will experience respiratory depression following adenotonsillectomy.

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