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Urgent Adenotonsillectomy

An Analysis of Risk Factors Associated with Postoperative Respiratory Morbidity

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Background: **The aim of this study was to determine the frequency and type of respiratory complications after urgent adenotonsillectomy (study group) for comparison with a control group of children undergoing a sleep study and adenotonsillectomy for obstructive sleep apnea syndrome. A second aim was to assess risk factors predictive of respiratory complications after urgent adenotonsillectomy.**

Methods: **The perioperative course of children who underwent adenotonsillectomy between January 1, 1999, and March 31, 2001, was reviewed. Two groups of children were identified from two different databases: the hospital database for surgical procedures (the study group) and the sleep laboratory database (the control group). The retrospective chart review focused on the preoperative status (including an evaluation for obstructive sleep apnea), anesthetic management, and need for postoperative respiratory interventions.**

Results: **A total of 64 consecutive cases for urgent adenotonsillectomy were identified, and 54 children met the inclusion criteria. Thirty-three children (60%) had postoperative respiratory complications necessitating a medical intervention; 11 (20.3%) required a major intervention (reintubation, ventilation, and/or administration of racemic epinephrine or Ventolin), and 22 (40.7%) required a minor intervention (oxygen administration). Six children (11.1%) required reintubation in the recovery room for respiratory compromise. Risk factors for respiratory complications were an associated medical condition (odds ratio, 8.15; 95% confidence interval, 1.81–36.73) and a preoperative saturation nadir less than 80% (odds ratio, 5.54; 95% confidence interval, 1.15–26.72). Sixteen (49%) of the medical interventions were required within the first postoperative hour. Atropine administration, at induction, decreased the risk of postoperative respiratory complications (odds ratio, 0.18; 95% confidence interval, 0.11–1.050.** ***Control group:*** **Of 75 children who underwent a sleep study and adenotonsillectomy, 44 had sleep apnea and were admitted to hospital after elective adenotonsillectomy. Sixteen (36.4%) children had postoperative respiratory complications necessitating a medical intervention. Six percent of the children (n = 3) required a major medical intervention. No child required reintubation for respiratory compromise.**

Conclusions: **Severe obstructive sleep apnea syndrome and an associated medical condition are risk factors for postadenotonsillectomy respiratory complications. Risk reductions strategies should focus on their assessment.**

THIS report is an extension of our previous work.[1] In 1999, we implemented a screening process based on overnight oximetry, performed at home or in the hospital, as a first test in studying children with suspected obstructive sleep apnea syndrome (OSAS). The result was an increase in the number of children being subjected to urgent adenotonsillectomy, where urgent adenotonsillectomy was defined as adenotonsillectomy that must be performed during the current hospital admission. Although a diagnosis of OSAS is known to increase the risk for postoperative respiratory morbidity from approximately 1%[2–4] to approximately 20%,[1,5–7] the rate and severity of respiratory complications associated with urgent adenotonsillectomy were excessive, culminating with two near respiratory arrests in March 2001. We thought that this high postoperative respiratory complication rate presented an opportunity to critically examine aspects of perioperative management that may have influenced the outcome.

Materials and Methods

The study design was retrospective and received institutional approval. Informed consent was not required. Subjects were identified from two databases. Although they have the same procedure code, urgent adenotonsillectomies have a different list code compared with elective adenotonsillectomies. This allowed the study group to be identified from the hospital computerized data log. The control group was identified from the sleep laboratory database. Children who had undergone urgent adenotonsillectomy comprised the study group. Children who had undergone a sleep study and elective adenotonsillectomy between January 1, 1999, and March 31, 2001, comprised the control group. The inclusion criteria were a diagnosis of OSAS and extubation in the operating room at the end of the adenotonsillectomy. The diagnostic criteria for OSAS were a clinical context consistent with obstructive sleep apnea plus:

1. an abnormal sleep study (see OSAS Severity) defined, in our institution, by an obstructive apnea and hypopnea index greater than 1 event per hour, or
2. an abnormal oximetry study defined by a trend graph showing at least three clusters of desaturations below 90% (fig. 1), or

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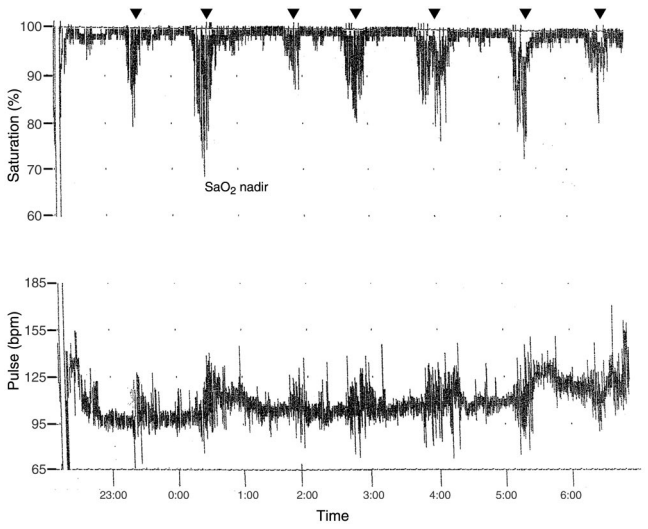

Fig. 1. Representative abnormal nocturnal oximetry study, recorded between 22:00 and 7:00 h, shows seven clusters (▼) of desaturations associated with an increase in heart rate variability. Four clusters show desaturations less than 80%. The arterial oxygen saturation (Sao_2) nadir is less than 80%. bpm = beats/min.

3. a carbon dioxide tension (from a capillary sample) in excess of 50 mmHg during rest while awake, or

4. witnessed severe upper airway obstruction and nocturnal desaturations below 90%.

Medical Chart Review

Pertinent history and operative and postoperative information were extracted from the medical record by a pediatric anesthesiologist (K. B. and/or C. H.). The start time of the operative procedure, the times of admission to and discharge from the postoperative unit, the time of opioid administration, and the time at which a respiratory complication occurred were all recorded. The duration of the operation was the combined anesthetic and surgical times. The postoperative period began on admission to the postoperative unit, either the pediatric intensive care unit or recovery room (postanesthesia care unit [PACU]), and ended with discharge from hospital. Postoperative day 1 began at 08:00 h on the day after surgery.

Both known (age, preoperative comorbidities, and nocturnal saturation nadir)[1,5,6,8] and potential (anesthetic technique) risk factors that might have contributed to postoperative respiratory morbidity were recorded.

Although the anesthetic technique varied, the rationale influencing the choice of induction technique, the choice of opioid, and the use of atropine at induction, muscle relaxants and reversal of nondepolarizing muscle relaxants could not be ascertained. The decision to administer intraoperative dexamethasone was often made by the operating surgeon on the basis of a difficult tonsillar dissection and uvular edema at the end of the adenotonsillectomy.

It is our routine to extubate children awake in the operating room. Children are transported to the postoperative unit in the lateral decubitus position. It is our routine to administer oxygen by facemask, attached to a Jackson Rees circuit, placed in close proximity to the child's face for the initial postoperative period. Although the child recovers in an oxygen-enriched environment, it is not possible to know the inspired concentration of oxygen during recovery. It is our routine to administer morphine, in repeated doses, as the opioid of choice in the postoperative unit until the child is able to tolerate oral codeine. In addition, we monitor all children admitted with a diagnosis of OSAS with an oximeter on the first postoperative night.

Postoperative events of interest included both respiratory complications and medical interventions. The respiratory complications were classified as *desaturation*, defined as a recorded oxygen saturation less than 95%, and *airway obstruction*, identified in the chart record by such words as "stopped breathing" or "apnea." It was sometimes difficult to distinguish respiratory depression from airway obstruction, but if the medical notes documented that the child was repositioned or the airway was supported, an obstructed breathing pattern was inferred.

The children were divided into two groups based on the need for medical intervention: those who required postoperative medical interventions for respiratory complications (INT group) and those who did not (non-INT group). Complications occurring intraoperatively, *i.e.*, before the child left the operating room, did not influence the grouping criteria.

Medical interventions were classified by complexity into minor and major interventions. Minor interventions (INT_{minor}), such as might be provided by a nurse, included oxygen therapy beyond usual period (identified from the chart record by a notation that oxygen was required beyond the initial check for vital signs) and/or repositioning of the child. Major interventions (INT_{major}), which required an assessment by a physician, included administration of racemic epinephrine, Ventolin, or Lasix; airway instrumentation with an oropharyngeal or nasopharyngeal airway or an endotracheal tube; and ventilation. Given the nature of a retrospective review, it was not possible to validate the appropriateness and efficacy of the medical interventions.

The time at which the medical intervention occurred relative to the time of admission to the postoperative unit was classified as (1) within the first postoperative hour, (2) between 1 and 8 postoperative hours, or (3) beyond 8 h. In addition, children experiencing multiple episodes of desaturation were identified.

Four tests were used to establish a diagnosis of OSAS: (1) polysomnography performed in the sleep laboratory, (2) cardiorespiratory sleep studies performed in the home, (3) overnight oximetry performed in the home or

hospital, and/or (4) an awake capillary carbon dioxide tension.

Sleep Study: Polysomnography or Cardiorespiratory Sleep Study

Details of our sleep study recording system have been published elsewhere.[1,9–12] Although the cardiorespiratory signals were analyzed for several variables, only the obstructive apnea and hypopnea index and the saturation nadir (Sao_2 nadir) are reported. The Sao_2 nadir was defined as the minimum validated hemoglobin oxygen saturation regardless of duration. In the cardiorespiratory study and polysomnography studies, the validity of the Sao_2 nadir was verified by visual inspection of a computerized data record.[10,13]

Oximetry Study

The oximetry studies present two types of graphic printouts: a trend graph and an event graph.[10] The trend graph displays a 6- to 12-h summary of the oxygen saturation and pulse rate (fig. 1). Apparent but artifactual desaturations that can be produced by low pulse amplitude or movement can be assessed with the event graphs, allowing a validation of the Sao_2 nadir.[13]

OSAS Severity

Of necessity, we stratified the OSAS disease severity by the Sao_2 nadir criteria alone because most children in the study group did not have values for the obstructive apnea and hypopnea index. We defined severe OSAS by an Sao_2 nadir less than 80% because this threshold has been shown to be associated with an increased risk of postadenotonsillectomy respiratory complications in a pediatric sleep laboratory referral population.[1,6]

Statistical Analysis

The variables were analyzed using SAS for Windows (version 8.02; SAS Institute, Cary, NC). Categorical data were summarized using frequencies, and continuous variables were reported as mean ± SD or ranges. For the purpose of the statistical analysis, adenotonsillectomy, tonsillectomy, and adenoidectomy were considered a single surgical entity.

The main outcome was the requirement for postoperative medical intervention. Potential risk factors were first evaluated with univariate analysis followed by multivariate logistic regression. Associations were tested by chi-square statistics and the corresponding Mantel-Haenszel odds ratio and 95% confidence intervals.[14] The threshold for statistical significance was $P < 0.05$. The relation between Sao_2 nadir and outcome was assessed descriptively with the Lowess smoothing curve, a robust locally weighted regression-smoothing curve, to verify our definition of severe OSAS[15] (fig. 2).

Differences between the control and study group were assessed with chi-square statistics for categorical variables and with a *t* test for continuous variables. The threshold for statistical significance was $P < 0.05$.

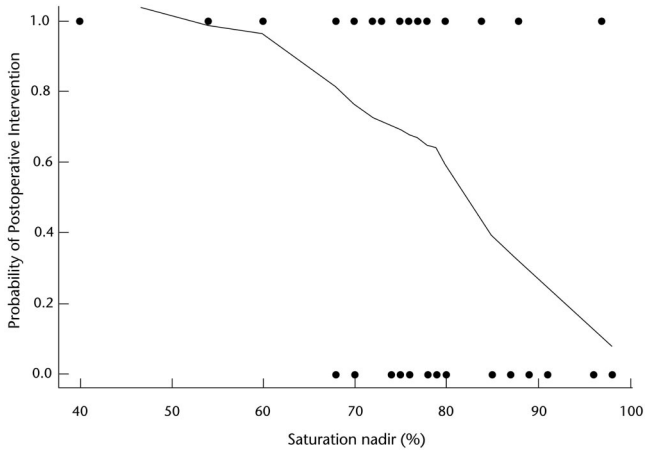

Fig. 2. Lowess probability plot[15] showing the weighted regression curve for the preoperative arterial oxygen saturation (Sao_2) nadir and the probability of an intervention after adenotonsillectomy. Inspection of the figure suggests that the Sao_2 nadir represents a continuum of risk for postoperative respiratory complications.

Results

The annual adenotonsillectomy caseloads for the years 1999 and 2000 were 843 and 761, respectively.

Study Group

Of 64 children who underwent urgent adenotonsillectomy, 54 met the inclusion criteria. Nine children were excluded because the indication for adenotonsillectomy was not OSAS (peritonsillar abscess = 4 diagnostic biopsy = 1, chronic sinusitis = 1, unstated = 3). One child remained intubated after surgery and therefore was excluded from further analysis.

Preoperative Status. There were 43 boys and 11 girls. The age and weight (mean ± SD) were 4.0 ± 2.4 yr and 22.4 ± 18.7 kg, respectively. There were 50 inpatients and 4 outpatients. The median time interval between the sleep study and surgery was 2 days (range, 1–61 days).

Associated Medical Conditions. Twenty-five children had associated medical conditions; 84% of these children required medical interventions (table 1).

OSAS Severity. Fifty-one children met the laboratory diagnostic criteria for OSAS (see Methods). In four children, a diagnosis of OSAS was made by clinical criteria alone. Fourteen children underwent a sleep study, 12 of which were a home cardiorespiratory sleep study and 2 of which were laboratory polysomnography. Forty-two children had oximetry studies. Thirty-one children had severe OSAS defined by a Sao_2 nadir less than 80%. Five of nine children had a preoperative capillary partial pres-

Table 1. Preoperative and Postoperative Data for the Study Group

	non-INT (%) (n = 21)	INT_{minor} (%) (n = 22)	INT_{major} (%) (n = 11)
Preoperative			
Age < 3 yr	45.0	31.8	27.3
Associated medical			
Nil	76.2	36.4	45.4
Asthma	9.5	22.7	27.3
Other	14.3	40.9	27.3
Preoperative Sao_2 nadir, %	80.6 ± 10.9	72.0 ± 11.7	77.1 ± 7.2
Children with preoperative Sao_2 nadir < 80%	50.0	85.0	50.0
Postoperative Sao_2 nadir, %			
Unit	96.8 ± 1.6	90.4 ± 6.2	76.6 ± 16.5
Ward	93.9 ± 3.6	84.9 ± 10.7	88.3 ± 2.9
Time interval before onset of respiratory complications			
1 h		36.4	72.7
1–8 h	No respiratory interventions	40.9	27.3
> 8 h		22.7	
Onset of respiratory morbidity			
< 2 h after postoperative opioid	No respiratory interventions	36.4	72.7
> 2 h after postoperative opioid	No respiratory interventions	31.8	9.1
No opioid	No respiratory interventions	22.7	18.2

Preoperative status and postoperative course for no (non-INT), minor (INT_{minor}), and major (INT_{major}) respiratory morbidity. Summary data are presented as mean ± SD or percent.

Sao_2 = arterial oxygen saturation.

sure of oxygen (Pco_2) during rest in excess of 50 mmHg (range, 39–71 mmHg).

Surgical Procedure. In the study group, 53 children underwent adenotonsillectomy, and 1 underwent adenoidectomy (patient 5 in table 2 had a diagnostic bronchoscopy in addition to adenotonsillectomy). The start time (24-h clock; mean ± SD) in the study group was 13:59 ± 3.0 h (group non-INT = 13:22 ± 2.4 h, group INT = 14:22 ± 3.4 h). The duration of surgery (mean ± SD) was 47.2 ± 14.9 min (group non-INT = 42.3 ± 12.3, group INT = 50.4 ± 15.7; $P = 0.05$).

Anesthetic Technique

Intraoperative. Although children in the study group were booked for urgent adenotonsillectomy, all fasted according to our guidelines for elective surgery. No child received a rapid-sequence induction. An inhalational induction (sevoflurane = 21, halothane = 2) was used in 41% of the children. The majority (93%) of the children received propofol during induction of anesthesia. Twenty-seven children received a muscle relaxant (rocuronium = 81%, succinylcholine = 19%). Rocuronium, when used, was given in a dose of 0.5 mg/kg. The tracheae of all children were intubated. All children received maintenance anesthesia with isoflurane. Forty-one children received rectal acetaminophen (32.8 ± 6.8 mg/kg). Intraoperative antiemetics were given to three children (droperidol = 2, dimenhydrinate = 1). The majority (98%) received an intraoperative opioid. The opioid dose (mean ± SD) was 1.04 mg/kg for codeine (n = 1), 0.08 ± 0.04 mg/kg for morphine (n = 12), 1.44 ± 0.62 μg/kg for fentanyl (n = 30), and 0.12 ± 0.04 μg/kg for sufentanil (n = 10). Thirteen children received intraoperative dexamethasone in a dose of 0.26 ± 0.18 mg/kg. Residual neuromuscular blockade in 7 of the 22 children who received rocuronium was reversed with neostigmine.

Postoperative. Eight children were admitted to the pediatric intensive care unit, and 47 were admitted to the PACU. Forty-seven of 54 children were assessed as having pain and were given an opioid (morphine = 44, fentanyl = 1, codeine = 2). The dose (mean ± SD) of morphine was 0.08 ± 0.04 mg/kg. Twenty-six children who received postoperative opioids required medical intervention. The onset of respiratory complications, in 12 children, occurred within 2 h of morphine administration.

Control Group

Of 75 children who underwent a sleep study and adenotonsillectomy, 44 had a positive sleep study and were admitted to hospital on the night after surgery (adenotonsillectomy = 41, adenoidectomy = 1, tonsillectomy = 2). There were 25 boys and 19 girls. The age and weight (mean ± SD) were 3.5 ± 1.9 yr and 18.9 ± 8.4 kg, respectively. The preoperative Sao_2 nadir was 86.0 ± 6.5%. Seven children had a preoperative Sao_2 nadir less than 80%. The obstructive apnea and hypopnea index was 14.2 ± 17.0 events/h. The median time interval between the sleep study and surgery was 60 days (range, 2–365 days). The median time interval between the sleep study and surgery, in children whose Sao_2 nadir was less than 80%, was 4 days.

An inhalational induction (sevoflurane = 35, halothane = 2, unknown = 12) was used in all children. An induction

Table 2. Respiratory Complications and Medical Interventions in Group INT_{major}

Patient	Age, yr	Preoperative Evidence for OSAS	Associated Medical Condition	Intraoperative			Course in PACU	Postoperative Medication before Major Intervention
				MR	Dexamethasone	Opioid		
1	5	Sao_2 nadir 80%	Asthma	Nil	N	Fentanyl	7.5 h after surgery: desaturations (89%), bradycardia (35 beats/min), UAO requiring nasopharyngeal airway	Fentanyl
			TGV				*Reintubation* 9.0 h after surgery	
			Developmental delay				RSV pneumonia	
							POD4: exacerbation of asthma and UAO necessitating nasopharyngeal airway	
2	4	Sao_2 nadir 70%	Asthma	Rocuronium	N	Morphine	Desaturation (< 80%) and UAO within 2 h of morphine dose	Morphine
		Pco_2 48 mmHg		Neostigmine			*Reintubation* 5.5 h after surgery	Racemic epinephrine
							Extubation on POD1	
3	3	Sao_2 nadir not reported	Nil	Nil	Y	Fentanyl	Desaturations (< 80%), UAO within 2 h of postoperative morphine.	Morphine
		Pco_2 51 mmHg					Difficult to rouse in morning 18 h after surgery: Pco_2 61 mmHg	Codeine
						RML infiltrate		
							Reintubation 17 h after surgery	
						Extubation on POD2		
4	3	Sao_2 nadir 80%	Asthma	Nil	Y	Fentanyl	Desaturation (75%) within 2 h of morphine dose	Morphine
		Pco_2 61 and 71 mmHg during sleep mmHg	Recent URTI				*Reintubation* 2 h after surgery	
							RML and LLL infiltrates	
							Extubation on POD1 and *Reintubation*	
							Extubation on POD6	
5	2	Sao_2 nadir not reported	Laryngomalacia	Nil	Y	Morphine	Stridor in first postoperative hour	Racemic epinephrine
			Failure to thrive				Fourth postoperative h difficult to arouse	
							Reintubation 6.5 h after surgery	
							Extubation on POD1.	
6	7	Sao_2 nadir not reported	Nil	Rocuronium	N	Morphine	Morphine within first 2 h after surgery	Morphine
		Pco_2 51 mmHg	Recent URTI				Desaturation (92%), UAO, Pco_2 71 mmHg	Racemic epinephrine
							Reintubation within 2 h of opioid	Ventolin
							Extubation on POD1	
7	6	Sao_2 nadir 68%	Developmental delay	Rocuronium	N	Nil	Desaturation (87%) within 2 h after surgery	Ventolin
			BPD				*Racemic epinephrine*	
			Vocal cord paresis				Transfer to PICU 3 h after surgery	

(*Table continues*)

Table 2. *Continued*

Patient	Age, yr	Preoperative Evidence for OSAS	Associated Medical Condition	Intraoperative			Course in PACU	Postoperative Medication before Major Intervention
				MR	Dexamethasone	Opioid		
8	7	Sao_2 nadir 84%	Obesity	Rocuronium	N	Fentanyl	Desaturation (80%) within 2 h of opioid.	Morphine
		Pco_2 53 mmHg	Asthma				*Racemic epinephrine*	
							Multiple desaturations	
9	4	Sao_2 nadir 70%	Nil	Nil	N	Fentanyl	*Racemic epinephrine*	Morphine
							Desaturations within 2 h of opioid	Codeine
10	2	Sao_2 nadir 88%	BPD	Nil	Y	Fentanyl	Desaturation (88%) within 2 h of opioid	Codeine
			Subglottic stenosis				*Racemic epinephrine*	Ventolin
			Developmental delay				Multiple episodes of desaturation	Lasix
							Postoperative pulmonary edema	
11	2.5	OAH index 32.3	Nil	Rocuronium	Y	Sufentanil	Laryngospasm on admission to PACU	Nil
		Sao_2 nadir 77%					Treated with succinylcholine and atropine, ventilation	

Eleven children required a major medical intervention, and details of their perioperative course are given below. The indications for adenotonsillectomy in patient 1 were both tonsillar abscess and obstructive sleep apnea syndrome (OSAS). Patients 8–10 were admitted electively to the post–intensive care unit (PICU), and patients 1–7 and 11 were admitted to the postanesthesia care unit (PACU). Six children, patients 1–6, required reintubation. Patient 7 required postoperative transfer from the PACU to the PICU.

BPD = bronchopulmonary dysplasia; INT_{major} = major medical intervention; LLL = left lower lobe; MR = muscle relaxant; OAH = obstructive apnea and hypopnea; Pco_2 = partial pressure of carbon dioxide; POD = postoperative day; RML = right middle lobe; RSV = respiratory syncitial virus; Sao_2 = arterial oxygen saturation; TGV = transposition of the great vessels; UAO = upper airway obstruction; URTI = upper respiratory tract infection.

dose of propofol was used in 93% of the children. A minority (22%) of the children received muscle relaxants (rocuronium = 8, succinylcholine = 2). The tracheae of all children were intubated. All children were given intraoperative opioids. One child received intramuscular codeine (0.98 mg/kg). The opioid dose (mean ± SD) was 0.07 ± 0.03 mg/kg for morphine (n = 10), 1.23 ± 0.54 μg/kg for fentanyl (n = 27), and 0.14 ± 0.05 μg/kg for sufentanil (n = 6). Three children received dexamethasone.

Study Group versus *Control Group*

Differences in age, weight, and sex were not significant. A greater proportion of children in the study group had an associated medical condition compared with the control group (45.5 *vs.* 13.6%; $P < 0.01$). Asthma was the most frequent associated medical condition in both groups. Although all of the children in the control group met our diagnostic criteria for OSAS, the disease severity was greater in the study group as evidenced by a lower preoperative saturation nadir (76.4 ± 11.1 *vs.* 86.0 ± 6.5%; $P < 0.05$) compared with the control group. More children in the study group had a preoperative Sao_2 less than 80% than in the control group (57.4 *vs.* 15.9%; $P < 0.001$).

The average start times in the study and control group were 13:57 ± 3.0 and 11:03 ± 2.3 h, respectively. The surgical procedure was longer in the study group compared with the control group (46.9 ± 14.9 *vs.* 40.3 ± 7.4 min, respectively; $P < 0.05$).

Certain aspects of the anesthetic technique differed between the two groups. Fewer children received reversal of rocuronium ($P < 0.05$) compared with the control group (table 3). The postoperative morphine doses in the study and control groups were 0.08 ± 0.04 and 0.09 ± 0.04 mg/kg, respectively.

Postoperative Respiratory Complications

Study Group. Sixty percent (n = 33) of the children in the study group required medical intervention in the postoperative period (table 1). (Two children experienced postextubation laryngospasm in the operating room, one had no other complications in the postoperative period, and the other required a minor medical intervention.) Forty-nine percent (n = 16) of the medical

Table 3. Comparison of the Anesthetic Management of Adenotonsillectomy in the Control and Study Groups

Drug Administration	Control Group (%) (n = 44)	Study Group (%) (n = 54)
Atropine	54.5	48.1
Muscle relaxant	22.7	50.0
Reversal of rocuronium	40.0	31.8*
Intraoperative opioid	100	98.1
Dexamethasone	6.8	24.1*
Postoperative opioid in first 2 h after surgery	95.5	87.0

Differences were assessed with chi-square statistics.

* $p < 0.05$.

Table 4. Timing of Postoperative Complications in Group INT_{major}

Patient	Clock Time of Admission to Postoperative Unit	Time Interval between Admission to Postoperative Unit and Major Medical Intervention, h	Clock Time of Reintubation	Time Interval between Admission to PACU and Reintubation, h
1	16:00	1.5	1:00	9.0
2	22:30	2.0	3:50	5.3
3	16:20	17.0	11:00 on POD1	17.7
4	11:10	2.0	13:15	2.1
5	15:00	5.5	21:30	6.5
6	17:50	1.0	22:15	4.4
7	13:05	2.0		
8	20:00	1.0		
9	12:00	1.0		
10	12:35	1.0		

Clock time (24-h clock) and time intervals (hours) between admission to the postoperative unit and the major medical intervention (INT) in 10 children in group INT_{major}. (Patient numbers correspond to numbering in Table 2. Patient 11, the child experiencing laryngospasm on admission to the postanesthesia care unit [PACU], is not included.) Patients 1, 3, and 4 were found to have postoperative pneumonia. Patients 1–7 were initially admitted to the PACU, and patients 8–10 were initially admitted to the post–intensive care unit (PICU) Patients 1–7 were transferred to the PICU.

interventions were required within the first postoperative hour. A third (n = 19) of the children experienced multiple episodes of desaturation in the postoperative period.

Five children were diagnosed with pneumonia in the postoperative period. Evidence for a diagnosis of pneumonia was fever, sputum, an abnormal chest radiograph, and initiation of antibiotic therapy. Three children had a preoperative Sao_2 nadir of 80%, and two had an elevated preoperative capillary Pco_2 (71 and 51 mmHg). Radiographic evidence of bilateral infiltrates in one child was consistent with pulmonary aspiration, although no documentation of such was noted.

Severity of Respiratory Complications

Group INT_{minor}. Twenty-two children required a minor medical intervention. All patients in group INT_{minor} experienced postoperative oxygen desaturation within 5.8 ± 4.8 h of admission to the postoperative unit. One child desaturated within 1 h of admission to the PACU and returned to the operating room for control of postadenotonsillectomy bleeding. She had no further desaturations.

Group INT_{major}. Eleven children required a major medical intervention (tables 1, 3, and 4). Seven children received racemic epinephrine. Six required tracheal reintubation. All children with preoperative hypercarbia required a major medical intervention. No child in the study group was given naloxone. Details of the postoperative course for each child are given in tables 3 and 4.

Control Group. Three children required medical intervention (naloxone administration = 2, oropharyngeal airway = 1) during emergence from anesthesia. Based on their postoperative course, two children were assigned to group non-INT, and one was assigned to group INT_{major}. Sixteen children (36.4%) in the control group required medical intervention in the postoperative period (INT_{minor} = 13, INT_{major} = 3). Six percent of the children experienced a major medical intervention (oropharyngeal airway = 1, Ventolin = 1, medical doctor assessment = 1). Twelve children experienced multiple desaturations during sleep on the first postoperative night and required oxygen. One child (2%) was diagnosed with pneumonia in the postoperative period. The postoperative Sao_2 nadir in the PACU was 82.0 ± 16.4%.

Analysis of Risk Factors

Study Group. The data were analyzed with univariate analysis for the known (age, associated medical conditions, OSAS severity)[1,5,6] and potential (administration of atropine at induction, dexamethasone, reversal of muscle relaxants) risk factors (table 5). Multivariate logistic regression identified an associated medical condition, an Sao_2 nadir less than 80%, and intraoperative dexamethasone administration as risk factors for postadenotonsillectomy respiratory morbidity. Atropine administration at induction reduced the risk of postoperative respiratory morbidity (table 6). A secondary analysis of data excluding dexamethasone administration, which may be a rogue risk factor (see Discussion), yielded similar results.

Table 5. Univariate Logistic Regression for Association between Postoperative Outcome (Intervention *vs.* No Intervention) and the Potential Risk Factors

Potential Risk Factors	OR	95% CL	*P* Value
Preoperative			
Age (≥ 3 yr *vs.* < 3 yr)	2.40	0.76, 7.55	0.13
Sao_2 nadir (< 80% *vs.* ≥ 80% or not reported)	2.75	0.88, 8.58	0.08
Associated medical condition (yes *vs.* no)	6.46	1.21, 2.91	0.003*
Intraoperative Administration			
Atropine (yes *vs.* no)	0.33	0.11, 1.05	0.06
Dexamethasone (yes *vs.* no)	4.30	0.85, 21.93	0.06
Neostigmine (no *vs.* yes or not appropriate)	1.25	0.36, 4.37	0.73

* $P < 0.05$, chi-square test.

CL = confidence limit; OR = odds ratio; Sao_2 = arterial oxygen saturation.

Table 6. Multivariate Logistic Regression for Association between Postoperative Outcome (Intervention *vs.* No Intervention) and the Risk Factors

Risk Factors	O Ratio	95% CL	*P* Value
Preoperative			
Sa_{O_2} nadir (< 80% *vs.* ≥ 80% or not reported)	5.54	1.15, 26.72	0.03*
Associated medical condition (yes *vs.* no)	8.15	1.81, 36.73	0.006*
Intraoperative Administration			
Atropine (yes *vs.* no)	0.18	0.11, 1.05	0.03*
Dexamethasone (yes *vs.* no)	5.43	0.91, 32.46	0.06

* $P < 0.05$, chi-square test.

CL = confidence limit; OR = odds ratio; Sa_{O_2} = arterial oxygen saturation.

Discussion

We report a 20.3% incidence of major respiratory complications after urgent adenotonsillectomy (study group) compared with an incidence of 6.1% in the control group. Although significant differences in the severity of the OSAS preclude extensive comparison between the study and control groups, the low incidence of postoperative complications in the control group and in a previous publication[1] confirms our clinical impression that the complication rate in the study group was excessive. In the study group, six children (11.1%) required postoperative reintubation, and five children (9.3%) developed postoperative pneumonia. Both early and late complications occurred. The onset of respiratory complications was often delayed and, in some children, began more than 8 h after surgery (table 1). Two clinical scenarios characterized the postoperative period. The clinical course in group INT_{minor} was one of episodic and repeated desaturation. The clinical course of children in group INT_{major} suggested worsening airway obstruction between admission to the postoperative unit and the need for a major medical intervention (tables 2 and 4).

Several factors may have contributed to the outcome, including patient factors (the presence of associated medical conditions and the severity of the OSAS) and other factors.

Associated Medical Conditions

The odds ratio for a medical intervention if an associated medical condition was present was 8.15 (95% confidence interval 1.81–36.7). Although this risk factor has been reported elsewhere,[1,5,6,16] the majority of children experiencing major respiratory complications reported by McColley *et al.*,[5] Rosen *et al.*,[6] and McGowan *et al.*[16] had cardiorespiratory, neuromuscular, or craniofacial comorbidities. Of note, the majority of children experiencing major postoperative complications in our study had either no comorbidity (n = 4) or asthma (n = 2).

Severity of OSAS

Disease severity in OSAS was an independent risk factor as evidenced by the fact that in the study group, an Sa_{O_2} nadir less than 80% had an odds ratio of 5.54 (95% confidence interval 1.15–26.72). Therefore, the high incidence of respiratory morbidity in the study group is explained in part by the fact that a higher proportion of the study population (57.4%) had severe OSAS, defined by a preoperative Sa_{O_2} nadir less than 80%, compared with the control group (16%) and our previous study population (26%).[1] Despite that the saturation nadir represents a single data point in the overnight oximetry study, the saturation nadir is a predictor of postoperative morbidity. Furthermore, although we treated the Sa_{O_2} nadir as a categorical variable with a cutoff threshold of 80%, inspection of figure 2 suggests that the Sa_{O_2} nadir may in fact represent a continuum of risk for postoperative respiratory complications, and this finding merits prospective study.

However, the complexity of the respiratory complications cannot be explained by the severity of the OSAS or coexisting medical conditions because the children in study group INT_{major} were older, with fewer comorbidities and a higher preoperative Sa_{O_2} nadir than children in study group INT_{minor} (table 1). Therefore, other factors, including preoperative preparation, intraoperative management, and postoperative care, may have influenced the outcome.

Preoperative Preparation

Support for the practice of urgent adenotonsillectomy based on abnormal oximetry was derived from experimental evidence suggesting that intermittent hypoxia adversely affects the developing brain and our disquiet in waiting for surgical intervention.[17] However, a pitfall in the use of oximetry alone in the diagnosis of OSAS is that lower respiratory tract infections,[18] asthma,[19] and pulmonary hypertension,[20] which coexist with OSAS, may also promote desaturation during sleep. It was not possible to comment on the adequacy of the preoperative preparation in the study group, but a 2-day time interval between the sleep test and surgery may not have been sufficiently long to allow for optimal preoperative preparation. The impact of aggressive preoperative preparation, including administration of antibiotics, bronchodilators, and oral and/or nasal steroids,[21,22] as a risk-reduction strategy to decrease respiratory morbidity after urgent adenotonsillectomy merits prospective study. For example, one child who was diagnosed with preoperative pneumonia and hypercapnia was managed with preoperative antibiotics, dexamethasone, oxygen, and a nasopharyngeal airway for several days before urgent adenotonsillectomy and experienced no postoperative respiratory complications.

Anesthetic Technique

To date, no differences in outcome have been attributed to anesthetic management.[5,6,16,23] We report that half of the complications occurred in the initial postoperative hours, a time period potentially influenced by anesthetic technique. Two aspects of anesthetic management may have affected outcome: the administration of atropine at induction and the decision not to reverse the intermediate nondepolarizing relaxant, rocuronium. Although administration of intraoperative dexamethasone was identified as a risk factor by statistical criteria (table 5), we suspect a selection bias because the decision to administer dexamethasone was based on clinical criteria (see Methods).

Atropine administration may be beneficial as a risk-reduction strategy in children with severe OSAS undergoing adenotonsillectomy.

The higher usage of neuromuscular blockade and the lower usage of neostigmine to reverse residual neuromuscular blockade in the study group compared with the control group are notable (table 3). This may be of clinical significance because not reversing nondepolarizing muscle relaxants has been reported to increase the risk of perioperative respiratory complications.[24] The child with OSAS may be vulnerable to residual neuromuscular blockade because OSAS is associated with an impairment in neuromuscular control of the upper airway, persisting despite adenotonsillectomy.[25,26]

Postoperative Care

Respiratory complications began within 2 h of postoperative opioid administration in 12 children (table 1). Although no study has shown that opioid administration affects outcome after adenotonsillectomy, all studies to date report a mixed population of OSAS, ranging from mild to severe disease.[1,5,6,23] In a developmental experimental model, a history of intermittent recurrent hypoxia has been shown to increase μ-opioid binding in the brainstem, suggesting an up-regulation of these receptors.[27] Such up-regulation may produce increased sensitivity to opioid drugs. If a similar phenomenon occurred in central opioid systems of children with severe OSAS, then this might be a mechanism whereby the margin of safety for opioid administration in these children would be reduced.

Other factors may also have affected outcome in the study group. Newland *et al.*[28] reported that the time of day is a risk factor for anesthesia related cardiac arrest. Bell *et al.*[29] speculated that uneven staffing patterns may contribute to the increased hospital mortality on weekends. In this regard, 5 of the 11 children who required a major medical intervention were admitted to the PACU after 13:00 h, coincident with a decrease in the medical and nursing staffing patterns. In addition, the nurse and physician–to–patient ratio is highest in a pediatric intensive care unit setting, and this may have influenced the complexity of the medical interventions because airway obstruction in children admitted to the pediatric intensive care unit was treated with racemic epinephrine, not reintubation (tables 2 and 4).

Conclusion

We report a high incidence of postoperative respiratory morbidity associated with urgent adenotonsillectomy, including an 11.1% incidence of reintubation and a 9.3% incidence of postoperative pneumonia. The rationale for urgent adenotonsillectomy based on documentation of a very low preoperative saturation nadir requires critical review. The temptation to react to the profound nocturnal desaturation with urgent adenotonsillectomy intervention should be balanced against the fact that these children are at increased risk for postoperative complications. To date, the most important predictors of postadenotonsillectomy respiratory morbidity are the presence of an associated medical condition and OSAS disease severity. Therefore, the preoperative evaluation of the child with OSAS should include an assessment of these risk factors. Overnight oximetry, a readily available test, may enable evidence-based decisions in the treatment of children with severe OSAS who require adenotonsillectomy.

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