An Anesthetic Management Protocol to Decrease Respiratory Complications After Adenotonsillectomy in Children with Severe Sleep Apnea

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BACKGROUND: A high incidence of respiratory morbidity after adenotonsillectomy is reported in children with obstructive sleep apnea syndrome (OSAS). In an effort to decrease this morbidity, we implemented perioperative guidelines recommending an adjustment in the administration of opioids, dexamethasone, and atropine in children with OSAS who demonstrated recurrent episodes of profound hypoxemia during the perioperative sleep study.

METHODS: We performed a retrospective review and compared results with historic data from 2001. The primary outcome variable was a major respiratory medical intervention ($MMI_{Respiratory}$). The severity of OSAS was classified with the McGill Oximetry Scoring (MOS) system, and our focus was on those children demonstrating repetitive desaturation <80% (MOS4).

RESULTS: The medical records of 292 children who underwent adenotonsillectomy between October 2002 and February 2006 met the inclusion criteria and 97 had been assigned MOS4. Eleven children (11.3%) required an $MMI_{Respiratory}$. In 2001, 8 children (29.6%), assigned MOS4, required an $MMI_{Respiratory}$. Comparing the new and old guidelines, the adjusted odds ratio for $MMI_{Respiratory}$ in MOS4 was 0.30 (95% CI: 0.10–0.85). The key elements achieving this reduction in $MMI_{Respiratory}$ were dexamethasone administration and a reduced opioid dosage. In 2002 to 2006, the intraoperative opioid dose, expressed in morphine equivalents, administered to the MOS4 group was 0.10 mg · kg^{-1} (0.06–0.12 mg · kg^{-1}), and the postoperative morphine dose was 0.02 mg · kg^{-1} (0–0.07 mg · kg^{-1}). Both doses were lower than the ones administered to the concurrent comparison group, P values <0.001.

CONCLUSIONS: A change in practice that included a dexamethasone administration and a reduction in opioid administration to children with profound recurrent hypoxia reduced the incidence of $MMI_{Respiratory}$ by >50%. (Anesth Analg 2010;110:1093–101)

Adenotonsillectomy is usually considered an uncomplicated surgery with a low risk for respiratory morbidity. However, postoperative respiratory complications occur more frequently when certain risk factors are present. These risk factors include age younger than 3 years, comorbidities such as airway anomalies, Down syndrome, and neuromuscular disease, and severe obstructive sleep apnea. A high apnea hypopnea index and repetitive episodes of profound hypoxemia during sleep increase the risk for postadenotonsillectomy respiratory morbidity at least 20-fold.[1–4] Following reports that the obstructive sleep apnea syndrome (OSAS) may also negatively affect growth, neurocognitive function, and cardiovascular physiology,[5–10] we implemented, in 2001, a clinical management protocol recommending expedited adenotonsillectomy and postoperative monitoring in the pediatric intensive care unit (PICU) for children with severe OSAS. However, children with the most severe OSAS, as indicated by repetitive decreases in hemoglobin saturation <80%, continued to experience a high incidence of major respiratory complications.[11]

We hypothesized that anesthetic technique was a potential factor contributing to this postoperative respiratory morbidity. Hence, our multidisciplinary group revised the perioperative guidelines to recommend a reduction in opioid use and administration of dexamethasone and atropine, specifically targeting children with severe OSAS. We compared data from 2 time periods: 2001 to 2002 (prerevision) and 2002 to 2006 (postrevision), focusing the analysis on children who demonstrated severe recurrent hypoxia on the perioperative sleep study.

METHODS

Diagnostic Methods for OSAS

Evaluation of sleep-disordered breathing was coordinated through our Sleep Laboratory, and a detailed description of our home oximetry method has been reported in previous publications.[12–15] Before oximetry testing, the parents completed a questionnaire that included demographic data, information about their child's past and present medical

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conditions, previous surgery, including adenotonsillectomy, and questions regarding their child's sleep pattern. These questions included those about sleep, breathing during sleep, and the degree of parental concern about breathing during sleep. Particular care was directed to the responses given for 3 questions concerning (1) difficulty breathing during sleep, (2) obstructive apnea observed by parents, and (3) frequency of snoring during sleep. After the parents received 30 minutes of instruction on oximetry testing, they took the oximeter home, conducted the study that same night, and returned the oximeter the following morning. Parents also completed a sleep log of their child's nocturnal behavior.

We used a motion-resistant pulse oximeter set with a 2-second averaging time for hemoglobin saturation (Masimo Radical, Version 4.1.0.0, Irvine, CA). Saturation and pulse rate data were extracted and analyzed using software (Download 2001, Version 2.5.0, Stowood Scientific Instruments, Oxford, England). This program provided a number of metrics for oxygenation, including the nadir saturation. Periods of oximetry recording were excluded from analysis if the oximeter quality signal indicated low signal, low perfusion, unrecognized, defective, or no sensor, interference, and ambient light.

An oximetry test was considered positive for OSAS if it had 3 or more desaturation clusters <90%. An oximetry study was assigned a McGill Oximetry Score (MOS) of 2, 3, or 4, based on the presence of at least 3 desaturations less than 90%, 85%, and 80%, respectively.[11] A MOS of 2 or higher was considered diagnostic of OSAS. An oximetry record not meeting the above criteria was inconclusive (MOS1), and in these children, the diagnosis of OSAS was established with polysomnography (Sandman, Pleasanton, CA). To establish a diagnosis of OSAS by polysomnography, we chose an objective measure, the polysomnographically determined mixed/obstructive apnea/hypopnea index ≥1 event per hour.[14] Children with values <1 were considered to be normal or to have simple snoring.[16]

The Revised Guidelines for Adenotonsillectomy in 2002 to 2006

Both guidelines recommended the expedited scheduling of adenotonsillectomy for children assigned MOS4 and admission of these children to the PICU in the postoperative period. Revisions in the guidelines focused on the administration of opioids, dexamethasone, and atropine (see Discussion for rationale). For children assigned MOS4, the guidelines advised a reduction in the intraoperative opioid dosage, but because the choice of intraoperative opioid varied from IM codeine to remifentanil, the dose was not specified. In addition, the guidelines recommended a reduction in the increment of IV morphine administered in the postoperative period. The perioperative guidelines for adenotonsillectomy specify a postoperative oral codeine (dose 1 $mg \cdot kg^{-1}$) to be administered regularly. The revised guidelines, in 2002–2006, recommended that in the MOS4 group, postoperative oral codeine should be administered only for a complaint of pain and therefore should be prescribed pro re nata (PRN). The revised guidelines recommended the administration of IV dexamethasone (0.3 $mg \cdot kg^{-1}$, maximum 10 mg) and atropine after induction of anesthesia.

The guidelines were discussed at departmental rounds and meetings, published in our anesthesia pocket manual, posted in the postoperative units, and implemented in October 2002. In addition, newly arriving anesthesia and surgical personnel, both resident and staff, were individually mentored regarding the new guidelines.

Method of Recruitment of Patients

Time Period 2002 to 2006 (Current Data)

The retrospective review received institutional approval. We retrieved consecutive cases from the hospital administrative database coded by surgical procedure for adenotonsillectomy with or without myringotomy and tube insertion. The hospital administrative database was also queried for both visits to the emergency room (ER Visit) and readmission to the hospital (Readmission) within 30 days of surgery.

Inclusion criteria were (1) OSAS and (2) documentation of a MOS. Exclusion criteria were (1) prior recruitment to research studies,[11,17] (2) surgical procedures additional to adenotonsillectomy/myringotomy and tube insertion, (3) a major medical intervention (MMI) in the perioperative period, (4) delayed extubation of the trachea, and (5) discharge from hospital on the day of surgery.

The charts of 591 children who underwent adenotonsillectomy between October 11, 2002 and February 24, 2006 were reviewed. Two hundred ninety-eight children with OSAS had been assigned a MOS. Six children were excluded because they required an $MMI_{Respiratory}$ in the perioperative period leaving a study population of 292 children, of whom 97 had been assigned MOS4.

Time Period 2001 to 2002 (Historic Data)

Nixon et al.[11] followed up prospectively 230 children referred to the sleep laboratory for evaluation between October 1, 2001 and September 30, 2002. The details of anesthetic management for those children who eventually underwent adenotonsillectomy had been recorded by K. Brown in a separate retrospective review that had also received institutional approval. In the relevant publication, Nixon et al.,[11] publishing in a nonanesthesia journal, did not report the details of this anesthetic management. This database was, however, available for comparison. In 6 children, all assigned MOS1, the adenotonsillectomy was performed after October 2002 and therefore overlapped the study period of the new guidelines. These children were reported by Nixon et al. and therefore were allocated to the 2001–2002 database. One hundred twenty-six children from the 2001–2002 time period met the inclusion criteria, and 27 children had been assigned MOS4. The surgical technique for adenotonsillectomy was an electrocautery dissection technique.

Because the choice of intraoperative opioid varied, opioid doses were converted to morphine equivalents: codeine = 0.08, demerol = 0.1, fentanyl = 100, hydromorphone = 5, remifentanil = 0, and sufentanil = 1000.[18] The intraoperative morphine equivalent (IOME) doses were expressed in $mg \cdot kg^{-1}$. Postoperative pain was assessed with the Children's Hospital of Eastern

Ontario Pain Scale (CHEOPS).[19] Pain was classified as mild, moderate, and severe based on the CHEOPS score recorded on admission to the postoperative unit, <6, 6 to 8, and >8, respectively. The cumulative postoperative dose of morphine, administered in the initial hour of recovery to achieve comfort, was recorded and expressed as $mg \cdot kg^{-1}$. If the postoperative oral codeine prescription was PRN, the codeine regimen was classified as PRN.

Outcomes

The primary outcome was an MMI for a respiratory event. $MMI_{Respiratoy}$ were identified from written comments in the anesthetic record and medical dossier. An $MMI_{Respiratoy}$ was defined as an intervention requiring a physician, such as instrumentation of the airway, bag/mask ventilation, and/or drug administration. (Neither antibiotic nor dexamethasone administration in the postoperative period was considered an MMI.)

Secondary outcomes were a minor medical intervention and prolonged hospitalization. Minor medical interventions, as might be performed by a nurse, included administration of oxygen and repositioning of the child's airway. It is our practice to administer blow-by-oxygen to all children recovering from anesthesia for the initial period in the postoperative unit. A notation of administration of oxygen implied that oxygen was required longer than usual to treat an episode of desaturation. The lowest saturation recorded in the postoperative period (SAT_{postop}) documented in the medical dossier was recorded.

Delayed discharge was defined as discharge from the hospital after postoperative day (POD) 1.

Statistical Analysis

Categorical variables were summarized by proportions. Continuous data were presented as median (25th–75th percentile) or mean ± SD.

Differences between 2001–2002 and 2002–2006 in the MOS4 group were assessed with χ^2 statistic or t test. The absolute risk reduction and number needed to treat for $MMI_{Respiratory}$ were determined. Multiple logistic regression was used to calculate the adjusted odds ratios (ORs) for known risk factors, age (<3 vs ≥3 years) and medical complexity,[1,2,11,20] and the guidelines (SPSS Version 16.0.1, SPSS, Chicago, IL).[21] In all statistical analyses, a P value <0.05 defined statistical significance.

RESULTS

Time Period 2002 to 2006 (Current Data)

Fourteen $MMI_{Respiratory}$ were required in 11 of the 97 children (11.3%) assigned MOS4: emergency succinylcholine (n = 2), reintubation (n = 4), insertion of oro- or nasopharyngeal airways (n = 3), administration of naloxone (n = 1), furosemide (n = 2), and nebulization of racemic epinephrine (n = 2). In 6 children, the $MMI_{Respiratory}$ occurred in the operating room (induction of anesthesia = 2). In the remaining 5 children, they occurred in the postoperative units: postanesthesia care unit (PACU) = 4 and PICU = 1 (Table 1).

Time Period 2001 to 2002 (Historic Data)

Eight of the 27 children (29.6%) assigned MOS4 required an $MMI_{Respiratory}$: emergency succinylcholine (n = 1), reintubation (n = 2), insertion of oropharyngeal airways (n = 3), bag/mask ventilation (n = 1), and nebulization of racemic epinephrine (n = 1). In 4 children, the $MMI_{Respiratory}$ occurred in the operating room (induction of anesthesia = 1). In the remaining 4, $MMI_{Respiratory}$ occurred in the PICU (Table 1).

The Concurrent Comparison Group: $MOS_{1,2,3}$

Although the guidelines focused on the children with the most severe OSAS, we also examined children with less severe OSAS, the MOS1, 2, and 3 groups. No statistically significant differences in (1) demographic variables, (2) adherence to elements in the guidelines, or (3) outcome were found among these MOS groups. Therefore, for each of the 2 time periods, 2001–2002 and 2002–2006, these children were combined to form a concurrent comparison group, $MOS_{1,2,3}$.

Demographic data, compliance with the guidelines, and outcome are presented in Table 2. In the MOS4 group, the incidence of $MMI_{Respiratory}$ decreased from 29.6% in 2001–2002 and to 11.3% in 2002–2006 (P = 0.032). The absolute risk reduction was 18.3%, and the number needed to treat was 6. Whereas in 2001–2002 the incidence of $MMI_{Respiratory}$ was 10-fold higher in the MOS4 group than $MOS_{1,2,3}$, in 2002–2006, there was no statistical difference in the incidence of $MMI_{Respiratory}$ between MOS4 and its concurrent comparison group, $MOS_{1,2,3}$.

Secondary Outcome

Minor $MI_{Respiratory}$

Overall, the lowest SAT_{postop} was higher than the nadir saturation ($nSAT_{preop}$), although in the majority of MOS4, the minimal postoperative saturation was <92% (Fig. 1).[22] Forty children (41%) in the MOS4 group required a minor medical respiratory intervention, and in the majority (n = 37), this intervention was administration of oxygen. In 2002–2006, 34 children, assigned MOS4, were initially admitted to the PACU. An escalation in nursing care for episodes of severe desaturation required a transfer from PACU to PICU for 3 of these children. In 2001–2002, 7 children assigned MOS4 were initially admitted to the PACU and 1 required transfer to the PICU for an escalation in nursing care.

The majority (55%) of children in the MOS4 group required a delayed discharge, a proportion not significantly different from the 2001–2002 time period. Reasons for delayed discharge in these 53 children were difficult to ascertain from the medical record but likely included respiratory concerns because desaturation on POD2 was documented in 65%.

In the MOS4 group, the readmission rate was 2%, and emergency room visits were 11%, values not significantly different from those in the concurrent comparison group, $MOS_{1,2,3}$: 4% and 11%, respectively.

Did Anesthetic Management Differ in MOS4 During 2002 to 2006?

In the MOS4 group, one-third of children received an IV induction, and the usual drug was propofol. In both time

Table 1. Summary of 19 Children Assigned MOS4 (Year 2002–2006 = 11) Requiring a $MMI_{Respiratory}$

Patient	Year	Age (y)	Medical complexity	Intraoperative dexamethasone	IOME ($mg \cdot kg^{-1}$)	POM ($mg \cdot kg^{-1}$)	Description of major medical intervention
$MMI_{Respiratory}$ occurring in the operating theatre							
Induction of anesthesia							
1	2001	1.2	No	No	Not applicable	Not applicable	Emergency succinylcholine[a]
2	2003	3.6	No	No	Not applicable	Not applicable	Emergency succinylcholine plus reoperation for bleeding plus postoperative respiratory failure[a]
3	2005	1.4	Pierre robin sequence	Yes	0.11	Not applicable	Emergency succinylcholine plus naloxone during emergence
Emergence from anesthesia							
4	2001	5.1	Asthma	Yes	0.21	Not applicable	OP airway postextubation
5	2001	15.8	No	Yes	0.1	Not applicable	OP airway postextubation[a]
6	2001	1.2	No	Yes	0.35	Not applicable	Reintubation[a]
7	2004	1.8	No	Yes	0.05	Not applicable	Bag mask ventilation postextubation[a]
8	2004	2.9	No	Yes	0	Not applicable	Reintubation plus furosemide[a]
9	2004	2.8	Broncho-pulmonary dysplasia	Yes	0.05	Not applicable	Reintubation plus furosemide[a]
10	2005	2.1	Developmental delay	Yes	0.30	Not applicable	Reintubation[a]
$MMI_{Respiratory}$ occurring in the PACU							
11	2004	6.6	Prader Willi syndrome	No	0.07	Not applicable	Reintubation[a]
12	2004	2.1	Developmental delay	Yes	0	0	NP airway[a]
13	2004	1.3	Developmental delay	Yes	0.04	0.02	NP airway[a]
14	2006	5.3	No	Yes	0.11	0.05	Racemic epinephrine
$MMI_{Respiratory}$ occurring in the PICU							
15	2001	5.0	Castleman syndrome	No	0.09	0.09	Racemic epinephrine
16	2001	2.1	No	No	0.32	0	OP airway
17	2001	3.7	No	Yes	0.07	0	Jaw thrust, bag mask ventilation
18	2001	4.1	Asthma	No	0.16	0	Racemic epinephrine, Reintubation
19	2005	2.2	Formerly premature	No	0.19	0.05	NP airway, racemic epinephrine

IOME = intraoperative morphine equivalent; MMI = major medical intervention; NP = nasopharygeal; OP = oropharyngeal airway; PACU = postanesthesia care unit; PICU = pediatric intensive care unit; POM = postoperative morphine; MOS = McGill oximetry score.

Dexamethasone and opioid administration before the $MMI_{Respiratory}$ is indicated. (Not applicable indicates that the $MMI_{Respiratory}$ occurred before the opioid was administered.)

[a] Admitted to PICU.

periods, two-thirds of children in the MOS4 group received an inhaled induction with sevoflurane. Atropine usage decreased in 2002–2006 (Table 2). A subanalysis in 2001–2002 reported an $MMI_{Respiratory}$ in 28.6% of group MOS4 who received atropine and in 30.0% of those children who did not. In 2002–2006, an $MMI_{Respiratory}$ was recorded in 17.3% of group MOS4 who received atropine but only 4.4% of those children who did not.

Dexamethasone and opioid usage also differed between the 2 time periods. There was an increase in dexamethasone usage ($P = 0.04$), and the dose administered was 0.24 $mg \cdot kg^{-1}$ (0.17–0.34 $mg \cdot kg^{-1}$). Compared with 2001–2002,

Table 2. Summary of Demographic Data, Anesthetic Management, and Outcome Comparing the MOS4 and the Concurrent Comparison Groups $MOS_{1,2,3}$ for Children Managed Under the 2001–2002 and 2002–2006 Guidelines

	MOS4		$MOS_{1,2,3}$	
McGill oximetry score	2001–2002	2002–2006	2001–2002	2002–2006
n	27	97	99	195
Demographics				
Gender (boys)	56%	74%	71%	65%
Age (y)	3.2 (2.1–4.7)	2.8 (2.1–4.3)	5.3 (2.6–5.8)	2.9 (2.2–4.1)
Age <3 y	44%	56%	31%	55%
Weight (kg)	12.4 (14.0–18.2)	13.6 (11.5–20.0)	16.0 (13.5–20.9)	14.0 (12.6–16.9)
Medical complexity (yes)	41%	31%	30%	25%
$nSAT_{preop}$ (%)	68 (60–71)	65 (56–73)	88 (84–92)	82 (78–87)
$nSAT_{preop}$ <80%	100%	96%	14%	33%
Elements of the guidelines				
Atropine (yes)	78%	53%*	49%	49%
Dexamethasone (yes)	48%	72%*	45%	67%
Opioids				
IOME ($mg \cdot kg^{-1}$)	0.13 (0.09–0.15)	0.10* (0.06–0.12)	0.12 (0.10–0.16)	0.11† (0.09–0.15)
POM ($mg \cdot kg^{-1}$)	0.04 (0.01–0.09)	0.02 (0–0.07)	0.10 (0.05–0.11)	0.10† (0.06–0.13)
PRN codeine (yes)	11%	63%‡	20%	28%†
Postoperative admission initially to PICU	74%	64%	4%	1%†
Primary outcome				
$MMI_{Respiratory}$	29.6%	11.3%*	3%	7%

IOME = intraoperative morphine equivalents; $MMI_{Respiratory}$ = major respiratory medical intervention; $nSAT_{preop}$ = preoperative nadir saturation; PICU = pediatric intensive care unit; POM = postoperative morphine; PRN = *pro re nata*; MOS = McGill oximetry score.

Differences between the MOS4 groups 2002–2006 vs 2001–2002 and MOS4, 2002–2006 and its concurrent comparison group. $MOS_{1,2,3}$ were assessed with χ^2 or *t* test.

* Statistical difference from MOS4, 2001–2002, $P < 0.05$.

† Statistical difference from MOS4, 2002–2006, $P < 0.001$.

‡ Statistical difference from MOS4, 2001–2002, $P < 0.001$.

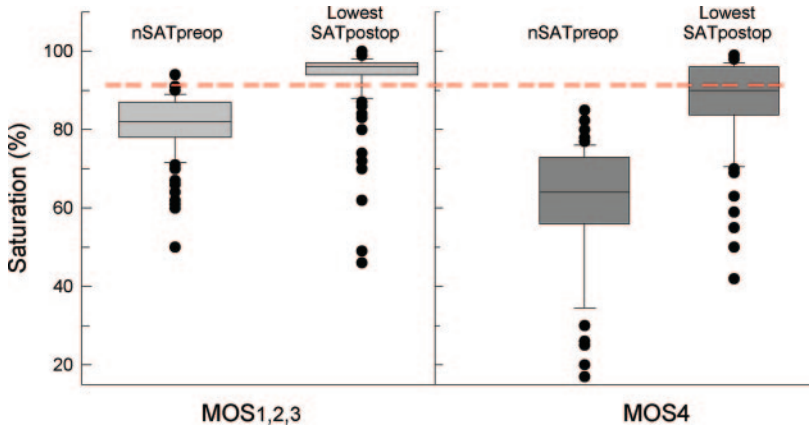

Figure 1. The perioperative saturation nadir ($nSAT_{preop}$) and the lowest recorded postoperative saturation (SAT_{postop}) for McGill Oximetry Score $(MOS)_{1,2,3}$ and MOS4 before and after adenotonsillectomy for obstructive sleep apnea syndrome (OSAS). The box plots display the median (line), 10th, 25th, 75th, and 90th percentiles and outliers. Outliers in $MOS_{1,2,3}$ with $nSAT_{preop}$ >92% met polysomnographic diagnostic criteria for OSAS (see Methods). Some children in both groups had episodes of profound desaturation after adenotonsillectomy. The dotted line indicates 92%, the normative threshold saturation nadir during sleep in children (see Marcus et al.[22]).

opioid usage in group MOS4 decreased as evidenced by a lower IOME ($P = 0.03$) and the PRN codeine regimen ($P < 0.001$, Table 2). Although in group MOS4 the median doses for postoperative morphine (POM) were not statistically different, the frequency histogram for POM in 2002–2006 was skewed leftward (Fig. 2). The POM dose required to achieve comfort was lower in the MOS4 group for all echelons of the CHEOPS (Fig. 3). In 2002–2006, compared with its comparison group $MOS_{1,2,3}$, the MOS4 group received statistically lower doses of all 3 elements of opioid therapy (Table 2 and Fig. 4).

Was the Reduction in Opioid Dosage Associated with Evidence of Less Optimal Pain Control?

The reduced IOME in group MOS4, relative to its concurrent comparison group, $MOS_{1,2,3}$, in 2002–2006 was not associated with a difference in the CHEOPS score recorded on admission to the postoperative unit ($n = 218$).

Overall, there was no statistical difference in the admission rate to PICU between the MOS4 groups. However, the trend over time was a decline in the proportion of children admitted to the PICU, decreasing from 100% in 2002 to 46% in 2005. By 2005, the majority of otherwise healthy children assigned MOS4 were not being admitted to the PICU (Table 3).

Other Observations

In the 2002–2006 time period, the choice of intraoperative opioid in the majority of the MOS4 group was fentanyl or sufentanil. Combinations of intermediate and long-acting opioids were used in 14 children. The intraoperative opiates administered to the remainder were remifentanil = 3, IM codeine = 1, morphine = 17, and nil = 4.

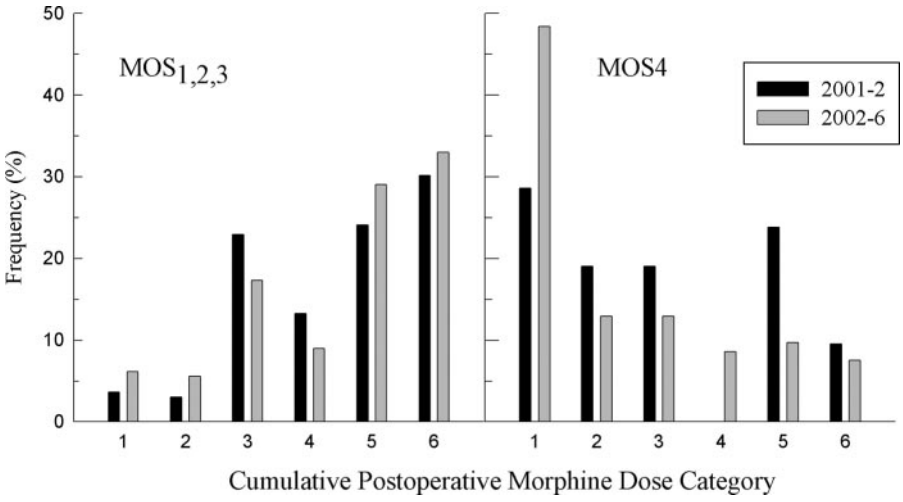

Figure 2. Histograms showing the frequency of cumulative postoperative morphine (POM) doses administered to achieve comfort in the initial recovery period. Cumulative postoperative morphine dose category: 1 = 0 ≤ 0.02; 2 = >0.02 ≤ 0.04; 3 = >0.04 ≤ 0.06; 4 = >0.06 ≤ 0.08; 5 = >0.08 ≤ 0.1; and 6 = >0.1 mg · kg^{-1}.

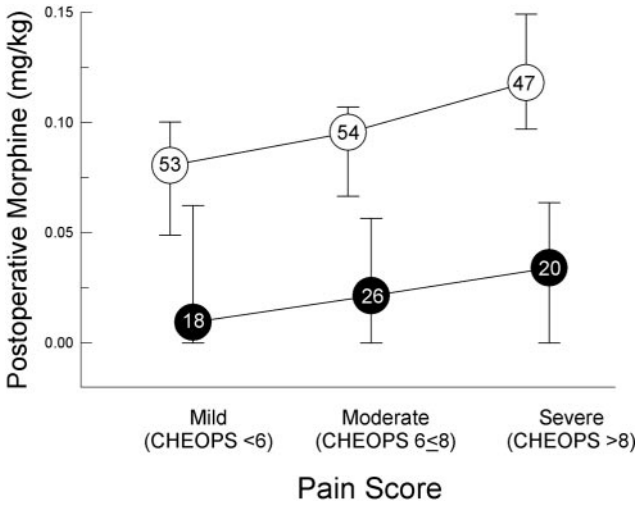

Figure 3. The cumulative postoperative morphine (POM) doses required to achieve comfort for 3 levels of pain severity. Children in McGill Oximetry Score (MOS)4 (closed circles) were administered a lower POM dose than the concurrent comparison group, $MOS_{1,2,3}$ (open circles) to achieve comfort, controlling for the admission Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) score. Data are displayed as median (25th to 75th percentile). Numbers within the symbols indicate the number of patients per group.

The time interval between the sleep study and surgery in the MOS4 group was 3 days (2–6 days). There were no clinically important differences in the usage of other anesthetic medications in the MOS4 groups or the concurrent comparison group, $MOS_{1,2,3}$. Operation time, that is, the time spent in the operating room, was longer in the MOS4 groups: 45 minutes (40–52 minutes) and 55 minutes (45–64 minutes) for time periods 2001–2002 and 2002–2006, respectively. Operation times for the concurrent comparison group, $MOS_{1,2,3}$, were similar: 40 minutes (35–47 minutes) and 42 minutes (35–50 minutes) for time periods 2001–2002 and 2002–2006, respectively.

The revised guidelines focused on the management of the MOS4 group, and no recommendations were made for the concurrent comparison group, $MOS_{1,2,3}$. The only clinically important difference in anesthetic technique between the 2 time periods in this comparison group was an increased dexamethasone usage in 2002–2006 (45% vs 67%).

A subanalysis of the 2002–2006 MOS4 group showed that 54% (n = 38) of children who received dexamethasone were discharged on POD1, a significantly higher proportion than those who did not receive it (23%) (P = 0.004). This pattern was not seen in the concurrent comparison group, $MOS_{1,2,3}$. Overall, however, management under the new guidelines did not achieve a statistically significant reduction in the duration of hospitalization, when compared with 2001–2002.

In 2002–2006, the incidence of reoperation for control of posttonsillectomy hemorrhage was 0.7%. One child (patient 2 in Table 1) required reoperation to control hemorrhage during the hospital admission, and a second child ($MOS_{1,2,3}$) required readmission and reoperation. Two children in group $MOS_{1,2,3}$ (dexamethasone = 1) experienced posttonsillectomy bleeding during the hospital admission but were managed conservatively. Eight additional children (dexamethasone = 7 and MOS4 = 4) were readmitted for posttonsillectomy bleeding and were managed conservatively.

Multiple Logistic Regression

The risk for $MMI_{Respiratory}$ was lower in the MOS4 group if managed with the 2002–2006 guidelines: OR 0.30 (95% CI: 0.11–0.86; P = 0.03). However, in 2002–2006, children in the MOS4 group were younger and had less comorbidity. Both young age and medical complexity are reported risk factors for respiratory morbidity after adenotonsillectomy.[1,2,23] Multiple logistic regression for these risk factors and the guidelines revealed that the adjusted ORs for young age and medical complexity did not achieve statistical significance but the adjusted OR for $MMI_{Respiratory}$ under the 2002–2006 guidelines remained significant: 0.30 (95% CI: 0.10–0.85; P = 0.02).

DISCUSSION

After implementation of perioperative anesthetic management guidelines for children with severe obstructive sleep apnea undergoing adenotonsillectomy, the incidence of major respiratory complications decreased from 29.6% in 2001–2002 to 11.3% in 2002–2006. Furthermore, whereas in 2001–2002 the incidence of $MMI_{Respiratory}$ in the MOS4 group was 10-fold higher than its concurrent comparison group, $MOS_{1,2,3}$, in 2002–2006, there was no statistical

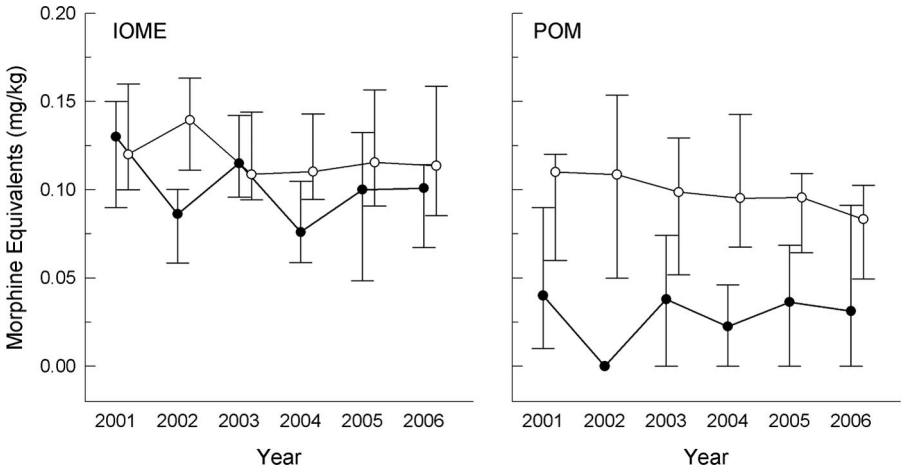

Figure 4. Trends in median (25th to 75th percentile) doses of intraoperative morphine equivalents (IOMEs) and the cumulative postoperative morphine (POM) doses administered between 2001 and 2006 in children with obstructive sleep apnea syndrome who were assigned a McGill Oximetry Score (MOS)4 (closed circles) and the concurrent comparison group, $MOS_{1,2,3}$ (open circles). Note that in MOS4, the 25th percentile for POM doses was 0 for 2003 through 2006.

Table 3. Trends in Practice in the MOS4 Group Between 2001–2002 and 2006

	2001–2002 guidelines	2002–2006 guidelines				
Year	2001	2002	2003	2004	2005	2006
n	27	7	29	26	26	9
Dexamethasone (yes)	48%	71%	69%	65%	77%	89%
Atropine (yes)	78%	29%	48%	65%	58%	44%
Codeine PRN	11%	29%	69%	50%	81%	100%
Postoperative admission initially to the PICU	74%	100%	86%	46%	46%	50%
Proportion of healthy children admitted to PICU	73%	100%	88%	47%	31%	50%
Proportion of medically complex children admitted to PICU	75%	100%	80%	55%	70%	66%

PRN = pro re nata; MOS = Mcgill oximetry score; PICU = pediatric intensive care unit.

difference between these 2 groups. These findings remained significant after control for known risk factors for perioperative complications in this patient group, specifically young age and medical comorbidities. Indeed, neither young age nor medical complexity achieved statistical significance as risk factors for $MMI_{Respiratory}$.

We defined a major respiratory complication as airway instrumentation or drug administration because these interventions were reliably identifiable in a retrospective review. However, 4 children from the MOS4 group, who had been admitted initially to the PACU, required transfer to a PICU for an escalation in nursing care. Reclassification of these 4 children in group MOS4 would have increased the incidence of $MMI_{Respiratory}$ in 2002–2006 to 14.4% and in 2001–2002 to 33.3%.

Elements common to both guidelines were expedited surgery and postoperative admission to the PICU. After reports that the OSAS may negatively affect neurocognitive and cardiovascular function,[5–10] we have advocated the expedited scheduling of adenotonsillectomy for severe OSAS. Accordingly, the delay between the oximetry test and surgery was 4 days in 2001–2002[11] and 3 days in 2002–2006.

The postoperative care location for children undergoing adenotonsillectomy has been a controversial subject. Although Helfaer et al.[24] reported an immediate improvement in sleep-related breathing after adenotonsillectomy, a high incidence of desaturation and respiratory complications occur on the first night after adenotonsillectomy in children with severe OSAS.[1,2,12,20,25] Oxygen saturation improved in the majority of children in group MOS4, but some continued to have very low saturations after surgery (Fig. 1), and oxygen was administered to 40%. Both the 2002–2002 and 2002–2006 guidelines recommended admission to a PICU for the MOS4 group. However, the temporal trends suggest that clinicians became more comfortable with PACU recovery in otherwise healthy children assigned MOS4. No increase in the rate of $MMI_{Respiratory}$ was evident as the admission rate to the PICU decreased. However, fewer than half of the children in group MOS4 were discharged the day after surgery, and reasons for prolonged hospitalization likely included respiratory concerns given the high incidence of desaturation on the second POD.

Because OSAS arises from dysfunction of the upper airway muscles leading to obstructive apnea[26] and because central muscarinic blockade is reported to enhance the function of genioglossus muscle,[27] we hypothesized that atropine might be beneficial. We had, in fact, previously reported that atropine administration decreased respiratory morbidity in children with severe obstructive sleep apnea.[20] These considerations notwithstanding, in 2002–2006 only 53% of children in the MOS4 group were given atropine, and its administration was associated with a 4-fold higher incidence of $MMI_{Respiratory}$.

The critical elements in the guidelines allowing an improvement in respiratory outcome seem to relate to a reduction in opioid usage and dexamethasone administration. Waters et al.[28] reported a heightened respiratory opiate sensitivity in children with severe OSAS. We reported an increased respiratory sensitivity to opioids after exposure to intermittent hypoxia in rat pups.[29] We have

also reported an increased analgesic sensitivity to opioids in children with OSAS who demonstrate profound recurrent hypoxia.[17,30] These findings justified our recommendation to reduce opioid dosage in the revised guidelines. The lower doses of intraoperative opioids in group MOS4 were not associated with higher CHEOPS score on admission to the postoperative unit, despite a 10-minute longer duration of time spent in the operating room. Whereas one-third of group $MOS_{1,2,3}$ required a cumulative POM dose in excess of 0.1 $mg \cdot kg^{-1}$ to achieve comfort, fewer than 10% of group MOS4 required this high dosage (Fig. 2). Furthermore, compared with the $MOS_{1,2,3}$ group, the dose of morphine to achieve comfort for all pain severities was lower in group MOS4 (Fig. 3). These findings support our hypothesis that children with severe OSAS, who display profound recurrent hypoxia, have a heightened analgesic sensitivity to opioids.

There was a shift to lower dosage of morphine administered in the postoperative period in the MOS4 group. In 2002–2006, the median POM dose required to achieve comfort in these children was 0.02 $mg \cdot kg^{-1}$. Administration of morphine in dosing increments of 0.05 to 0.1 $mg \cdot kg^{-1}$ might have resulted in administration of excessive morphine to children in the MOS4 group, three-quarters of whom required a cumulative dose of POM <0.07 $mg \cdot kg^{-1}$. Indeed, in an earlier publication, we reported that a cumulative POM dose of 0.08 $mg \cdot kg^{-1}$, administered to children with a comparable severity of OSAS, was associated with a high (11%) reintubation rate after adenotonsillectomy.[20]

Termination of obstructive apnea in children with OSAS is achieved by the automatic recruitment of the upper airway dilating muscles to reopen the obstructed pharynx.[31–33] The recent report of a selective respiratory inhibition of the genioglossus muscle by fentanyl raises the possibility that this reflex mechanism may be impaired by opioids.[34] Preemptive administration of codeine, with regularly prescribed doses, will require that the sleeping child is awakened for administration of codeine, regardless of the pain complaint. If the child then resumes sleep, the opioid might depress this reflex. The principal advantage of a PRN codeine regimen is avoidance of this scenario.

A major limitation of this study was the lack of a pain metric beyond the CHEOPS score recorded on admission to the postoperative unit. Indeed, Fortier et al.[35] reported that postoperative pain in the majority of children undergoing ambulatory adenotonsillectomy is inadequately treated. Their findings led the authors to recommend the preemptive administration of codeine after adenotonsillectomy. Our data, in contrast, support the notion that a subgroup of children with OSAS and profound recurrent desaturation, the MOS4 group, displays a heightened sensitivity to opioids and are better managed when codeine is titrated to the severity of the pain complaint. There is an urgent need to determine the optimal codeine regimen in children undergoing adenotonsillectomy for OSAS.

Reported consensus opinion is that dexamethasone promotes an earlier return to oral intake after adenotonsillectomy.[36] Its antiinflammatory and morphine-sparing properties[37,38] coupled with a heightened analgesic sensitivity to opioids may have facilitated a reduction of opioid dosage in the MOS4 group, without adversely affecting pain control. There was good compliance with the recommendation for dexamethasone over time, and two-thirds of the children ($n = 196$) in 2002–2006 received dexamethasone. This suggests that dexamethasone administration was indeed a credible element in the guidelines. Although there has been recent concern that the use of dexamethasone might increase perioperative bleeding after tonsillectomy,[39,40] we report only 2 cases of reoperation for control of posttonsillectomy hemorrhage, and only 1 of these 2 children received dexamethasone.

Limitations of the Study

The guidelines only focused on the MOS4 group, and one-third of patients in the concurrent comparison group, $MOS_{1,2,3}$, had nSAT <80%. Although we have reported a strong inverse correlation between $nSAT_{preop}$ and analgesic sensitivity,[17,30] the duration, frequency, and intensity of the stimulus by which intermittent hypoxia alters μ-opioid receptor functionality has yet to be demonstrated. Additional children with less profound degrees of recurrent hypoxia may also have benefited from a lower opioid dosage.

The study was retrospective. However, studies of postadenotonsillectomy respiratory compromise in children with severe OSAS are poorly suited to a prospective randomized clinical trial study design. Taken as a whole and spanning a decade of practice, management under the new guidelines reduced the incidence of major respiratory complications occurring outside of the operating room in children with OSAS and profound recurrent hypoxia from a high of 19.4% in 1999–2000[20] to 5.2%. Similarly, our reintubation rate in the postoperative units decreased from 9.8%[20] to 1.3%.

These findings suggest that dexamethasone administration and a reduction in opioid dosage decrease the risk for respiratory complications in children with severe OSAS who undergo adenotonsillectomy with an electrocautery technique. In children who demonstrate profound recurrent hypoxia, we strongly recommend a reduction opioid dosage, specifically a decrease in the IV POM dosing increment to 0.02 $mg \cdot kg^{-1}$. Future studies should assess the implications of our findings to ambulatory adenotonsillectomy programs and, in the broader picture, to pain management in patients with obstructive sleep apnea.

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