Children with severe OSAS who have adenotonsillectomy in the morning are less likely to have postoperative desaturation than those operated in the afternoon

[Les enfants atteints d'un SAOS sévère, opérés pour amygdalectomie le matin, sont moins susceptibles de désaturation postopératoire que les opérés d'après-midi]

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Purpose: To determine, in a subset of children previously reported, if the time of day when adenotonsillectomy for severe obstructive sleep apnea syndrome (OSAS) was performed affected the incidence of postoperative respiratory complications.

Clinical features: Children having adenotonsillectomy were included if they had a polysomnographic diagnosis of severe OSAS within six months prior to operation. Patients who met the inclusion criteria were grouped by the occurrence of postoperative desaturation into a saturated (SAT) and desaturated (deSAT) group. The charts of children in group deSAT were reviewed. The clock time of the surgical procedure was recorded and categorized as morning (AM) or afternoon (PM).

Results: Eighty-eight patients met the inclusion criteria. There were 31 girls and 57 boys. The mean ± SD age (yr) and weight (kg) were 4.6 ± 2.9 yr and 20.8 ± 14.5 kg respectively. There were 63 children in the SAT group and 25 in the deSAT group. Differences in age, weight and gender were not significant. The preoperative oxygen saturation (SaO_2) nadir for the SAT and deSAT groups was 80.8 ± 10.2% and 67.6 ± 17.5% ($P < 0.05$) respectively. The preoperative obstructive apnea and hypopnea index was 15.8 ± 10.2 and 35.7 ± 34.6 events·hr^{-1} ($P < 0.05$), respectively. Surgery in 63 (71.6%) children was performed in the AM. Univariate logistic regression identified PM surgery [odds ratio (OR) 4.6, 95% confidence interval (CI) 1.7 to 12.6, $P = 0.002$] and a preoperative SaO_2 nadir < 80% (OR 3.6, 95% CI 1.4 to 9.4, $P = 0.009$) as risk factors predicting postadenotonsillectomy desaturation.

Conclusion: Children with severe OSAS whose surgery is performed in the AM are less likely to desaturate following adenotonsillectomy than children whose surgery is performed in the PM.

Objectif : *Déterminer, chez un sous-groupe connu d'enfants, si l'heure à laquelle l'amygdalectomie a été réalisée pour un syndrome sévère d'apnée obstructive du sommeil (SAOS) a un effet sur l'incidence de complications respiratoires postopératoires.*

Éléments cliniques : *Des enfants subissant une amygdalectomie ont été inclus dans notre étude si un diagnostic polysomnographique de SAOS sévère avait été établi dans les six mois avant l'opération. Les patients admis ont été répartis selon l'occurrence de désaturation postopératoire dans un groupe de saturation (SAT) ou de désaturation (deSAT). Les dossiers des enfants du groupe deSAT ont été révisés. L'heure de l'opération a été notée sous matin (AM) ou après-midi (PM).*

Résultats : *Ont été admis à l'étude, 88 patients dont 31 filles et 57 garçons. La moyenne d'âge et de poids ± l'écart type étaient respectivement de 4,6 ± 2,9 ans et 20,8 ± 14,5 kg. Il y a eu 63 enfants dans le groupe SAT et 25 dans le groupe deSAT. Les différences d'âge, de poids et de sexe n'étaient pas significatives. Le niveau préopératoire minimal de saturation en oxygène (SaO_2) a été de 80,8 ± 10,2 % et de 67,6 ± 17,5 % ($P < 0,05$) dans les groupes SAT et deSAT respectivement. Les indices d'apnée obstructive et d'hypopnée préopératoires étaient de 15,8 ± 10,2 et de 35,7 ± 34,6 événements·h^{-1} ($P < 0,05$), respectivement. L'opération de 63 (71,6 %) enfants s'est faite en AM. Une analyse univariée de régression logistique a considéré l'opération réalisée en PM [risque relatif (RR) de 4,6, intervalle de confiance (IC) de 95 %, 1,7 à 12,6, $P = 0,002$] et un niveau minimal de SaO_2 préopératoire < 80 % (RR de 3,6, IC de 95 %, 1,4 à 9,4, $P = 0,009$) comme des facteurs de risque prédictifs de désaturation postamygdalectomie.*

Conclusion : *Les enfants atteints d'un SAOS sévère, opérés en AM, sont moins susceptibles de subir une désaturation postamygdalectomie que les enfants opérés en PM.*

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ADENOTONSILLECTOMY is one of the commonest operations performed in children with the annual caseload in excess of a quarter million in the USA alone.[1] In the UK about 2.3/1,000 children under the age of 12 yr undergo tonsillectomy annually.[2]

Children with the obstructive sleep apnea syndrome (OSAS) have a higher risk for respiratory morbidity following adenotonsillectomy compared with the general pediatric population.[3–5] Quality assurance programs have focused attention on patient characteristics contributing to postoperative risk.[6] An evolving viewpoint emphasizes the need to look beyond the patient, to factors in the health delivery system *per se*, which may affect outcome. Newland *et al.*[7] reported that surgery performed after 15:00 hr was associated with a higher risk for anesthetic-related cardiac arrest. Using our large database of children with OSAS who have undergone adenotonsillectomy, we aimed to assess the time of day of surgery as an independent risk factor for postadenotonsillectomy respiratory morbidity. A second aim was to examine the time interval between postoperative opioid administration and respiratory outcome.

Methodology

The study received Institutional approval.

Patient selection criteria

The selected patients represent a subset of children previously reported.[5] The inclusion criteria were: 1) a sleep study documenting severe OSAS; 2) adenotonsillectomy within six months prior to surgery; and 3) extubation in the operating room at the end of surgery. The diagnostic criterion for severe OSAS was an abnormal sleep study defined, in our institution and elsewhere,[8] by an obstructive apnea and hypopnea (OAH) index > 5 events·hr^{-1}.

Chart review and study parameters

DIAGNOSTIC CRITERIA FOR OSAS

A diagnosis of OSAS was made with either polysomnography performed in the sleep laboratory or a cardiorespiratory sleep study performed in the home. Details of our sleep study recording systems have been published elsewhere.[9–12] Although the studies were analyzed for several variables,[5] only the OAH index and the preoperative saturation nadir (preSaO_2 nadir) are reported. The preSaO_2 nadir was defined as the minimum hemoglobin oxygen saturation regardless of duration and was validated by visual inspection of a computerized data record.[10,13]

POSTOPERATIVE CARE FOLLOWING ADENOTONSILLECTOMY

It is our practice to extubate children when awake in the operating room and 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. We administer *iv* morphine, in repeated doses (0.05 mg·kg^{-1}), as the opioid of choice in the postoperative care unit until the child is able to tolerate oral codeine. In addition we monitor all children with a diagnosis of OSAS with an Nellcor N200 oximeter (Nellcor, Pleasanton, CA, USA) on the first postoperative night. Postoperative events of interest included both respiratory complications and medical interventions. Postoperative respiratory desaturation was defined as a room air oxygen saturation less than 95%. Administration of oxygen, insertion of an oropharyngeal airway, reintubation and ventilation were considered medical interventions.

MEDICAL CHART REVIEW

The children were divided into two groups based on the presence of postoperative desaturation into a desaturated (deSAT) or saturated (SAT) group. Desaturation which occurred before the child left the operating room, did not influence the grouping criteria.

Pertinent history, operative and postoperative information were recorded including the start time of the operative procedure. Outcome was assessed from written reports in the nursing and medical records. A review of medical charts was conducted for children in the deSAT group. The number of desaturations in the first 24 hr postoperative period, as documented in the medical chart, were recorded by a pediatric anesthesiologist (A.K.). The clock time of opioid administration and the clock time at which a respiratory complication occurred were recorded. The temporal relationship between opioid administration and the first (postdeSAT$_{1st}$) and minimum (postSaO_2 nadir) were determined. The "sleep state" reported in the nursing charts as "awake" or "asleep" at the time of desaturation was noted.

RELATIONSHIP BETWEEN POSTOPERATIVE MORPHINE ADMINISTRATION AND POSTOPERATIVE DESATURATION

Children who did not desaturate in the postoperative period (group SAT) were assigned a value for postSaO_2 nadir of 95%. The difference between the postdeSAT$_{1st}$ and postSaO_2 nadir was calculated. The time intervals: 1) between the postSaO_2 nadir$_{1st}$ and opioid administration immediately preceding it (Interval$_{1st}$); and 2) between the postSaO_2 nadir and

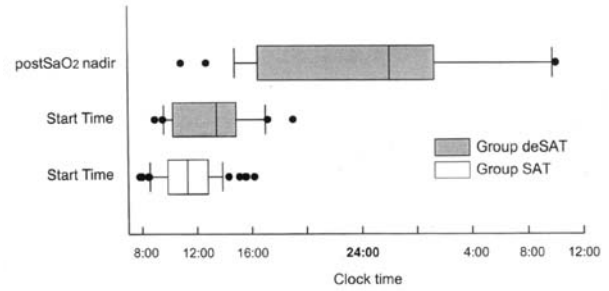

FIGURE Timing of events
Box plot distribution of data for the start time of surgery in group SAT and deSAT. Data is also given for the clock time at which the post oxygen saturation (SaO_2) nadir occurred in group deSAT. The median clock time for the postSaO_2 nadir was 23:00 hr.

opioid administration immediately preceding the episode ($Interval_{nadir}$) were calculated. Opioid dosing was converted to equianalgesic morphine doses, such that the relative potencies for codeine, fentanyl and sufentanil were 0.1, 100 and 1,000 respectively.[14] The mean dose of opioid, administered in the initial three hours, was calculated as the sum of the intraoperative plus the first two postoperative hours (opioid-three hours) dose. The mean dose of opioid, administered in a 24-hr period during and following surgery (opioid-24) was also calculated.

Statistical analysis

The variables were analyzed using SAS for Windows (version 8.02, SAS Institute, Cary, NC, USA). Categorical data were summarized using frequencies and continuous variables were reported as mean ± SD or ranges.

Known risk factors namely young age, a low oxygen saturation nadir and an associated medical condition, were categorized as age risk (< 3 yr or ≥ 3 yr), oxygen saturation (SaO_2) nadir risk (< 80% or ≥ 80%) and associated medical condition risk (yes *vs* no).[3,4] Surgery performed between 7:45 and 12:59 was designated morning (AM) and after 13:00 was designated afternoon (PM). The season for surgery performed between October and March was assigned to winter and for surgery performed between April and September was assigned to summer. Since the majority of children received postoperative opioids, opioid administration could not be evaluated as an independent risk factor. Opioid dosing, converted to morphine equivalents, was treated as a continuous variable.

The main outcome was the occurrence of desaturation following adenotonsillectomy. Risk factors were first evaluated with univariate analysis followed by multivariate logistic regression.[15] Associations were tested by Chi squared statistics.

Results

There were 31 girls and 57 boys. The mean ± SD age (yr) and weight (kg) were 4.6 ± 2.9 yr and 20.8 ± 14.5 kg, respectively. Twenty-seven percent (n = 24) of children had an associated medical condition (asthma = 13, cardiac = 2, neuromuscular = 1). The preoperative SaO_2 nadir was 77.1% ± 13.9 (range 20%–90%). The preoperative OAH index was 21.5 ± 22.0 (range 5–142.2) events·hr^{-1}.

The hospital stay was 38.6 ± 34.9 hr. The minimum stay in hospital was eight hours. Sixty-six children were discharged prior to 24 hr postoperatively. Four children were discharged the same day of surgery, 9.9 ± 1.4 hr after surgery. (SaO_2 nadir = 82.8% ± 12.7, OAH index = 14.6 ± 12.3 events·hr^{-1}). Sixty-two children were discharged the AM following surgery, mean stay in hospital was 23.4 ± 9.4 hr (SaO_2 nadir = 79.0 ± 12%, OAH index = 16.2 ± 10.7 events·hr^{-1}).

There were 63 (71.6%) patients who did not experience postoperative desaturation (SAT group) and 25 (28.4%) children who did (deSAT group). The distribution of known and potential risk factors is given in Table I. Differences in age, weight, gender and the presence of an associated medical condition were not significant. The preoperative SaO_2 nadir for the SAT and deSAT groups was 80.8 ± 10.2% and 67.6 ± 17.5%, respectively ($P < 0.05$). The preoperative OAH index was 15.8 ± 10.2 and 35.7 ± 34.6 events·hr^{-1}, respectively ($P < 0.05$).

Surgery was performed in the winter season in 45 (51%) children. The mean ± SD duration of surgery was 49.1 ± 11.5 min. Differences in the duration of surgery were not significant. Surgery was performed in the AM in 63 (71.6%) children. The time of surgery (24 hr clock) for groups SAT and deSAT was 11:24 ± 2.03 hr and 13:09 ± 2.7 hr, respectively.

The anesthetic technique varied. An *iv* induction was used in 62.5% of children (n = 55). Propofol was administered to 60 children whereas sodium pentothal was used in 18. Anesthesia was maintained with isoflurane (n = 23), halothane (n = 59) or sevoflurane (n = 4) and unrecorded in two. The trachea of all children were intubated for the adenotonsillectomy. Atropine was administered at induction of anesthesia in 63% (n = 55) of children. Non-opioid adjuncts were administered to 44 children (acetaminophen = 19, ketorolac

TABLE I Risk factors for postadenotonsillectomy desaturation

Risk factor	*Group deSAT (n = 25)*	*GroupSAT (n = 63)*	*P-value*
Age			
< 3 yr	10	19	NS
≥ 3 yr	15	44	
Associated medical condition			
Yes	10	14	NS
No	15	49	
SaO_2 nadir			
< 80%	16	21	$P < 0.05$
≥ 80%	9	42	
Clock time of surgery			
PM	13	12	$P < 0.05$
AM	12	51	
Time of year			
Winter	10	35	NS
Summer	15	28	

Two by two Table for known (age, medical conditions, obstructive sleep apnea syndrome severity) and potential (time of day, season of year) risk factors. Differences in the preoperative SaO_2 nadir during sleep and clock time of surgery were statistically significant by Chi squared analysis. SaO_2 = oxygen saturation; AM = morning; PM = afternoon.

TABLE II Univariate analysis of risk factors for postadenotonsillectomy respiratory complications

Potential risk factor	*OR*	*95% CI*	*P-value*
Age			
≥ 3 yr *vs* < 3 yr	0.65	0.25–1.70	0.376
Associated medical condition			
yes *vs* no	2.33	0.86–6.32	0.091
SaO_2 nadir			
< 80% *vs* ≥ 80%	3.56	1.35–9.38	0.009
Time of year			
Winter *vs* summer	0.53	0.21–1.37	0.188
Clock time of surgery			
PM *vs* AM	4.60	1.68–12.58	0.002
Opioid dose	1.01	0.21–4.81	0.993

The odds ratio (OR) for a preoperative SaO_2 nadir < 80% during sleep and surgery performed in the afternoon were significant risk factors by statistical criteria. Opioid dosing was treated as a continuous variable. SaO_2 = oxygen saturation; AM = morning; PM = afternoon.

= 25). Seventy-one children received a muscle relaxant (atracurium = 1, rocuronium = 43, vecuronium = 13, succinylcholine = 14). Thirty-seven (65%) children who had received a nondepolarizing muscle relaxant did not receive a reversal agent. Seventy-six (86.4%) children received an intraoperative opioid (morphine = 6, fentanyl = 37, sufentanil = 31, codeine = 2). Differences in anesthetic management between the SAT and deSAT groups were not significant.

In the postoperative period 87 children received acetaminophen. Antiemetics were administered to a minority of children (droperidol = 4, dimenhydrinate = 1). Seven (8%) children (group SAT = 3, group deSAT = 4) did not require any postoperative opioid in the first 24 hr. Sixty-nine (78.4%) children received an opioid in the first two postoperative hours (morphine = 66, meperidine = 1, codeine = 2). Oral codeine was the most frequently administered opioid beyond the initial two postoperative hours (codeine = 62, morphine = 1).

The main outcome was the occurrence of postoperative desaturation. Univariate analysis of known[3,4] and potential risk factors identified two risk factors: the preoperative SaO_2 nadir risk (< 80% *vs* ≥ 80%) and the time of day of surgery (PM *vs* AM; Table II). These risk factors remained significant when analyzed with a multivariate analysis. In addition, multivariate analysis gave an OR for the season (winter *vs* summer) of 0.27, (95% confidence interval 0.08–0.94, $P = 0.04$).

Secondary analysis of the mean number of desaturations recorded for the first postoperative 24-hr period, was 2.0 ± 1.0. Overall the value for the postSaO_2 nadir was 16.2 ± 13.0% higher than the preSaO_2 nadir. The post$deSAT_{1st}$ and postSaO_2 nadir were 90.4 ± 4.3% and 88.6 ± 4.6% respectively. The median clock time for the first and minimum desaturation was 17:30 and 23:00, respectively (Figure 1). The median time interval between surgery and respiratory complications was 3.3 hr (range 67 min to 21 hr). The time interval between the first and minimum postoperative desaturation ranged from 0 to 13 hr (2.5 ± 3.8 hr). Eighteen (72%) patients were asleep at the time of post$deSAT_{1st}$ and 21 (84%) patients were asleep at the time of the postSaO_2 nadir.

Four (16%) patients had received no opioid prior to the postoperative desaturation. The mean dose for opioid-three hours (morphine equivalents, $mg \cdot kg^{-1}$) was 0.21 ± 0.13 and for opioid 24 hr (morphine equivalents, $mg \cdot kg^{-1}$) was 0.48 ± 0.30. Differences in opioid dosing between groups SAT and deSAT were not significant. The time interval between opioid administration and the first postoperative desaturation was 4.2 ± 4.5 hr (range 0.5–17.3 hr).

The medical interventions required in the deSAT group were O_2 administration (n = 25) and airway instrumentation (oropharyngeal airway = 2, bag and mask ventilation = 4, reintubation = 1).

Discussion

This report has several limitations inherent in a retrospective review. Recording of events may not be complete and it is likely that we under report the true incidence of

desaturation. In addition, it was not possible to report reliable data on a history of recent upper airway infections, which might have influenced the occurrence of desaturation following surgery.[16,17] We used a threshold of 95% to define postoperative desaturation, since this threshold is a criterion for discharge in our institution. Overall the postoperative saturation nadir increased 16% from the preoperative SaO_2 nadir, a finding which is in agreement with that of Helfaer *et al.*[18] However, one third of children in our study desaturated < 95% on the first postoperative night and were given O_2.

Several factors may have contributed to desaturation in the postoperative period, including severity of OSAS, and the time of day at which surgery occurred.

OSAS severity

Although we sought to restrict the analysis to a homogenous population of children with severe OSAS, the fact that $preSaO_2$ nadir was lower and the OAH index higher in the deSAT group suggests our population of severe OSAS was not as homogeneous a population as intended. In this regard, there is an emerging consensus that OSAS severity is an independent risk factor for respiratory morbidity.[3,4,18,19] Furthermore the criteria for stratification of OSAS disease severity for diagnosis and prediction of postoperative respiratory morbidity probably differ. As an example, the criterion for a diagnosis of severe OSAS is an OAH index > 5 events·hr,$^{-1}$ [20] whereas that for prediction of postadenotonsillectomy respiratory morbidity is an OAH index > 10 events·hr^{-1}.[4] There is a need to develop criteria applicable to an operative setting which define perioperative risk stratification in OSAS.

Time of day of surgery

Surgery performed in the AM in children with severe OSAS was associated with a lower risk for postoperative desaturation compared with those having their operation in the PM and we propose two explanations for this finding. First, children who are operated on in the AM have a longer time to recover from the effects of anesthesia before their first postoperative nocturnal sleep. Second, postoperative children may be better observed by day staff and alert parents early in the day.

The shortened time interval, between postoperative morphine dosing and bedtime, imposed by PM surgery may have contributed to the incidence of postoperative desaturation, given the exaggerated respiratory depression to opioids which has recently been reported in children with severe OSAS.[21] It is noteworthy that the majority of desaturation (72%) occurred during sleep. Pediatric OSAS is a disease of rapid eye movement (REM) sleep. Proportionally, REM sleep increases and respiratory function is at its nadir, later in the sleep period.[12,22] There is a strong possibility that the combination of opioids and sleep promote desaturation following adenotonsillectomy in children with severe OSAS.

A recent study reported that hospital admissions and surgeries performed on weekends were associated with a higher mortality than on weekdays, a finding attributed to lower staffing patterns on weekends.[23] The median clock time at which the $postSaO_2$ nadir occurred was 23:00 hr, coincident with the lowest staffing ratio. The child with severe OSAS may benefit from the close supervision afforded by a high nurse and physician staffing ratio.

Conclusion

Children with severe OSAS whose surgery is performed in the AM are less likely to desaturate following adenotonsillectomy than children whose surgery is performed in the PM. Surgery performed in the AM, could represent a cost-effective risk reduction strategy to decrease postadenotonsillectomy respiratory complications in children with severe OSAS which merits prospective study.

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