

# Planning Adenotonsillectomy in Children With Obstructive Sleep Apnea: The Role of Overnight Oximetry

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**ABSTRACT.** *Objective.* Obstructive sleep apnea (OSA) in children is usually effectively treated by adenotonsillectomy (T&A). However, there may be a waiting list for T&A, and the procedure is associated with an increased risk of postoperative complications in children with OSA. Needed is a simple test that will facilitate logical prioritization of the T&A surgical list and help to predict children who are at highest risk of postoperative complications. The objective of this study was to develop and validate a severity scoring system for overnight oximetry and to evaluate the score as a tool to prioritize the T&A surgical list.

*Methods.* This study comprised 3 phases. In phase 1, a severity score was developed by review of preoperative overnight oximetry in children who had urgent T&A in 1999–2000. In phase 2, the score was validated retrospectively in 155 children who had polysomnography (PSG) before T&A in 1992–1998. In a phase 3, a 12-month prospective evaluation of a protocol based on the score was conducted.

*Results.* In phase 1, a 4-level severity score was developed on the basis of the number and the depth of desaturation events (normal to severely abnormal, categories 1–4). In phase 2, the McGill oximetry score correlated with severity of OSA by PSG criteria. In phase 3, a clinical management protocol was developed based on the score. Of 230 children tested, 179 (78%) had a normal/inconclusive oximetry (category 1) and went on to have PSG. Those with a positive oximetry (categories 2–4; 22%) had no additional sleep studies before T&A. Timing of T&A was based on oximetry score, leading to a significant reduction in waiting time for surgery for those with higher oximetry scores. Postoperative respiratory complications were more common with increasing oximetry score.

*Conclusions.* Overnight pulse oximetry can be used to estimate the severity of OSA, to shorten the diagnostic and treatment process for those with more severe disease, and to aid clinicians in prioritization of T&A and planning perioperative care. *Pediatrics* 2004;113:e19–e25. URL: <http://www.pediatrics.org/cgi/content/full/113/1/e19>; *oximetry, obstructive sleep apnea, child, adenotonsillectomy, postoperative complications.*

ABBREVIATIONS. OSA, obstructive sleep apnea; T&A, adenotonsillectomy; PSG, polysomnography; CRSS, cardiorespiratory sleep study; SaO<sub>2</sub>, arterial oxygen percent saturation; AHI, apnea-hypopnea index.

Obstructive sleep apnea (OSA) is a common condition in childhood, affecting approximately 1% to 3% of children.<sup>1,2</sup> The morbidity associated with OSA includes sleep disruption, failure to thrive, and cor pulmonale.<sup>3</sup> In addition, potential neuropsychological and cognitive consequences are being increasingly recognized, including lower academic performance<sup>4,5</sup> and higher rates of behavioral problems,<sup>6</sup> when compared with unaffected children of the same age. Most otherwise normal children with OSA have adenotonsillar enlargement, and adenotonsillectomy (T&A) is usually a highly effective treatment.<sup>7,8</sup>

Approximately 6% to 12% of healthy children have habitual snoring.<sup>1,2,9</sup> In this group, clinical history and examination findings fail to distinguish clinically significant OSA from benign snoring (snoring without impairment of oxygenation or ventilation and without sleep disruption).<sup>10</sup> Polysomnography (PSG), involving an overnight stay in a sleep laboratory, provides a detailed evaluation of both sleep quality and breathing during sleep<sup>11</sup> and is currently the best method available for diagnosis of OSA.<sup>12</sup> However, in many centers, such an evaluation either is not available or involves a considerable waiting time. In addition, waiting lists for T&A may be long and clinicians must prioritize cases for surgery. For these reasons, alternatives to full PSG for the evaluation of suspected OSA are often sought.<sup>13</sup>

Periodic clusters of desaturation on continuous overnight recording of oxygen saturation with 3 or more desaturations <90% has been demonstrated to have a 97% positive predictive value for OSA in otherwise healthy children.<sup>14</sup> Since September 2000, children without other medical problems and with a history strongly suggestive of OSA plus a positive overnight oximetry<sup>14</sup> have been referred directly for T&A in our center, without proceeding to a more detailed sleep study. It had been our practice to expedite T&A in children with more severe desaturation during sleep, rather than have these children wait on the surgical waiting list. This practice was based on experimental evidence of the effects of severe intermittent hypoxia on the developing brain<sup>15</sup> and on our disquiet in waiting several months for

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definitive treatment in young children with severe episodic desaturation. To formalize this prioritization process, we set out to develop a scoring system for overnight oximetry that is easily applied; reflects the severity of the underlying OSA; and can be used by pediatricians, sleep physicians, respiratory physicians, anesthesiologists, and otolaryngologists to prioritize patients who require T&A. This article presents the development of such a score and its validation and a prospective evaluation of a clinical management protocol based on the score.

## METHODS

Development and evaluation of a severity scoring system for overnight oximetry was undertaken in 3 phases: 1) development of the criteria for the score; 2) comparison of the score with polysomnographic markers of OSA severity; and 3) prospective evaluation of a clinical management protocol based on the score, to determine whether use of the score had the desired effect of expediting surgical treatment for those with more severe OSA.

### Phase 1: Development of the Oximetry Score

The goal for phase 1 was to establish an easily implemented oximetry scoring system that reflected consensus opinion about what constitutes a mildly, moderately, or severely abnormal oximetry. Children who had T&A performed on the urgent operating list at the Montreal Children's Hospital between January 1, 1999, and March 31, 2001, were identified from the operating room record. This group was chosen because it was an easily defined group that would be expected to include a number of children with severe OSA. T&A was being performed on an urgent basis because of a high level of clinical concern on the part of the treating physician and/or otolaryngologist.<sup>16</sup> In cases in which continuous overnight oximetry had been performed preoperatively, the overnight oximetry trend and individual desaturation events were reviewed by 3 independent raters (G.M.N., G.M.D., and R.T.B.).<sup>14,17</sup> Pulse oximetry was performed using either a Nellcor (Pleasanton, CA) N-200 (mode 2, fast averaging) or N-3000 oximeter. Identifying features were removed from the records so that the raters were unaware of the child's clinical details. Each evaluator ranked the tests in order of severity, and then the list was divided into the following groups, with the criteria for inclusion in each category being determined individually and independently by each rater: 1) normal or inconclusive oximetry recording,<sup>14</sup> and therefore not able to exclude OSA without additional evaluation of breathing during sleep; 2) mildly abnormal study, predictive of OSA<sup>14</sup> necessitating T&A but not on an urgent basis; 3) markedly abnormal study, with a pattern consistent with OSA, requiring surgery on an expedited basis (arbitrarily defined as within 2 weeks); and 4) severely abnormal study, with a pattern consistent with OSA, requiring surgery on an urgent basis (arbitrarily defined as within 1–2 days, with admission to hospital for stabilization before surgery).

The list of rankings was then compared, and objective criteria were determined for each of the above categories, after discussion between the scorers. This step in the development of the score was

undertaken to determine the level of agreement between experienced observers of overnight oximetry as to what constitutes an abnormal study and to translate that consensus opinion into objective criteria for determining severity. The final scoring system criteria are shown in Table 1. Examples of overnight oximetry trend graphs for each score are shown in Fig 1.

### Phase 2: Retrospective Validation of the Score

This scoring system (Table 1) was then applied to the overnight oximetry tests performed as part of in-laboratory PSG or a home cardiorespiratory sleep study (CRSS)<sup>18</sup> for evaluation of suspected OSA between 1992 and 1998. Detailed information on the perioperative course of children in this cohort has been published previously.<sup>19</sup> Each overnight oximetry test was scored by a single investigator (G.M.N.), without knowledge of the results of the PSG/CRSS or the postoperative course of the patient. The oximetry score was then correlated with indices of severity of OSA as defined by the PSG/CRSS. The incidence of intervention for respiratory compromise in the postoperative period was also compared between the groups. Major postoperative respiratory compromise was defined by a requirement for 1 or more of the following interventions, from the time of emergence from anesthesia: ventilation with a bag and mask, administration of continuous positive airways pressure, reintubation, administration of medication for airway compromise or respiratory distress, placement of an oropharyngeal/nasopharyngeal airway, and/or unplanned admission to the pediatric intensive care unit for respiratory compromise. Minor postoperative respiratory compromise was defined by a requirement for oxygen therapy beyond the usual period (15–30 minutes postoperatively) or repositioning of the child to improve airway patency.

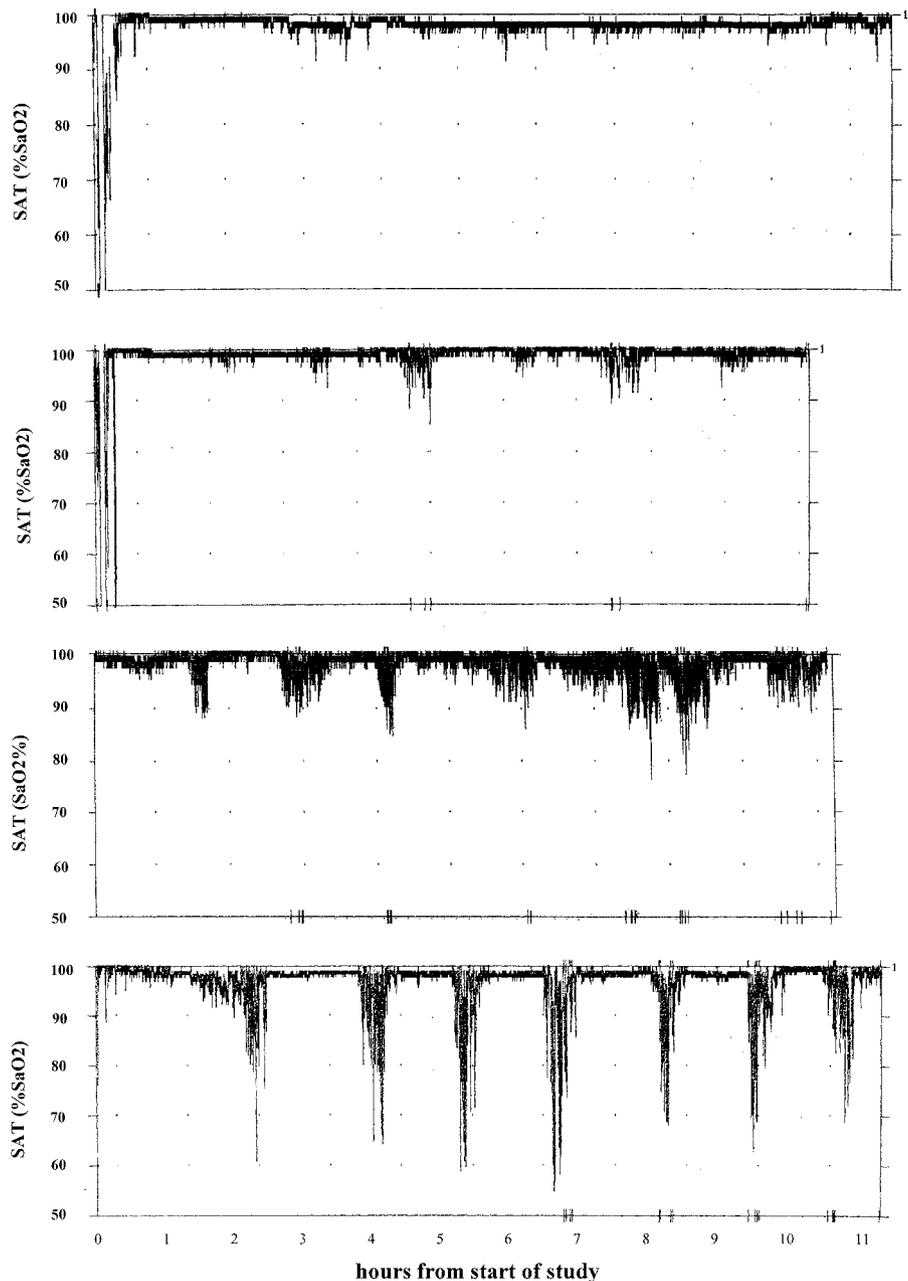
### Phase 3: Prospective Evaluation of the Score

After the above evaluation, we began systematically performing overnight oximetry as a first test in children who were referred to the sleep laboratory with suspected OSA. A parent comes to the sleep laboratory to obtain the oximeter, receives instruction in its use, performs the test on the child at home overnight, and returns the oximeter to the laboratory for downloading and interpretation the following morning. Occasionally, the test was performed on an inpatient when the medical team suspected OSA. Consecutive patients who were referred for suspected OSA from October 1, 2001, until September 30, 2002, were included in the analysis. The patient group represents a clinical group of children with adenotonsillar hypertrophy and includes a small number of children with other medical conditions (see Results).

We devised a clinical management protocol based on the oximetry score for children undergoing T&A for OSA, after the results of the retrospective analysis found that the oximetry score correlated with severity of OSA and predicted a higher risk of postoperative respiratory compromise. Children who had an oximetry score of 1 (normal/inconclusive) were scheduled for a more comprehensive sleep study. Those with an oximetry score of 2 were referred to an otolaryngologist for T&A on an elective basis. For those with a score of 3, surgery was recommended on an expedited basis, preferably within 2 weeks of the oximetry test. Children in this group were to be treated postoperatively in the postanesthetic care unit for the first night, with continuous arterial

**TABLE 1.** The McGill Oximetry Scoring System Devised in Phase 1 and Validated in Phases 2 and 3

Oximetry Score	Comment	Criteria			Recommendation
		No. of Drops in SaO <sub>2</sub> <90%	No. of Drops in SaO <sub>2</sub> <85%	No. of Drops in SaO <sub>2</sub> <80%	
1	Normal study/ inconclusive for OSA	<3	0	0	Baseline: stable (<3 clusters of desaturation) and >95%
2	OSA, mild	≥3	≤3	0	Three or more clusters of desaturation events <sup>14</sup>
3	OSA, moderate	≥3	>3	≤3	Three or more clusters of desaturation events <sup>14</sup>
4	OSA, severe	≥3	>3	>3	Three or more clusters of desaturation events <sup>14</sup>



**Fig 1.** Examples of the oxygen saturation trend graphs from overnight oximetry tests: from top to bottom, categories 1 to 4.

oxygen percent saturation ( $\text{SaO}_2$ ) monitoring. Children with an oximetry score of 4 were referred for T&A on an emergency basis, with the aim of performing T&A within 24 to 48 hours of the oximetry test. Children with an oximetry score of 4 had a preoperative evaluation including a chest radiograph, complete blood count, electrocardiogram and early-morning capillary blood gas, and an anesthetic consultation. Postoperatively, those with a score of 4 were admitted electively to the pediatric intensive care unit, with continuous monitoring as for category 3. Details of the postoperative course were assessed from the patient records by an anesthesiologist (K.B.) who was blinded to the preoperative oximetry score. Major and minor respiratory compromise was defined as for phase 2.

For assessing the ease of use and interobserver repeatability of the oximetry score, 3 clinicians not involved in the development of the score were asked to evaluate 100 overnight oximetry recordings. The independent scorers were a clinical fellow in pediatric respiratory medicine, a clinical fellow in anesthesiology, and a sleep laboratory technologist. The last had experience in use of the score; the first 2 scorers had not used the scoring system before, and the anesthesiology fellow had no experience in interpreting overnight oximetry records. A training session in interpretation of

overnight oximetry was provided to each scorer by the same investigator (G.M.N.), including explanation of the definition of a cluster of desaturation events and identification of movement artifact-related desaturation events.<sup>14,17</sup> This was followed by a practice run using 4 oximetry recordings that were not part of the evaluation. The entire teaching session took approximately 20 minutes. The overnight oximetry recordings from 100 consecutive children who were referred for evaluation of suspected OSA after October 1, 2002 (including those used in phase 3) were then presented to the scorer in random order. This group included unselected tests with proportions of each severity as is usually seen in referred patients. No additional clinical information was provided. The time taken to determine the score was recorded for each oximetry test, and the scores were compared with the score assigned to the test at the time it was performed (scored by R.T.B. or G.M.N.).

### Statistical Analysis

Statistical analysis was performed using the SPSS for Windows program, version 9.0.0 (SPSS Inc, Chicago, IL). Comparisons between scorers in the development of the score and evaluation of its

use are made using the weighted  $\kappa$  statistic.<sup>20</sup> This method for measuring agreement with ordinal data assigns weight based on the magnitude of observed disagreement so that disagreement between categories 2 and 3 is given less weight than between categories 2 and 4, for example. The relationships between oximetry score and PSG results were analyzed using Kruskal-Wallis analysis of variance; posthoc analyses used Dunnett's C test. Proportions of subjects in each oximetry category requiring postoperative respiratory intervention were compared using Kendall's  $\tau$ -b (for ordinal variables) or Fisher's exact test when any group contained <5 subjects. Waiting time for surgery was not normally distributed; thus, median waiting times are given and compared between groups using Kruskal-Wallis analysis of variance.

## RESULTS

### Phase 1: Development of the Scoring System

Of the 64 children who had T&A on the urgent surgical list between January 1, 1999, and March 31, 2001, 31 had preoperative overnight oximetry recordings available for analysis. Without instruction in how to categorize the oximetry studies, the overall interrater agreement among the 3 scorers was 56%. Much of the variation between scorers was crossover between categories 3 and 4, with an average weighted  $\kappa$  statistic of 0.55 reflecting moderate agreement.<sup>20</sup> After discussion of differences, the scorers agreed on objective and easily implemented criteria for each category (Table 1).

### Phase 2: Retrospective Validation of the Score

Between October 1992 and April 1998, 349 children were referred to the Sleep Laboratory at Montreal Children's Hospital. Of these, 163 had T&A ( $n = 143$ ), adenoidectomy ( $n = 14$ ), or tonsillectomy ( $n = 6$ ) performed within 6 months of the PSG/CRSS.<sup>19</sup> Pulse oximetry recorded during the preoperative sleep study was available for review in 155 (95%) of the surgical cases, 80% of which were performed during a CRSS performed in the child's home.<sup>18</sup>

Children with higher oximetry scores had more severe OSA by PSG/CRSS criteria (Table 2). Higher oximetry scores were associated with a higher apnea-hypopnea index (AHI;  $P < .001$ ), higher desaturation index ( $P < .001$ ), lower SaO<sub>2</sub> nadir ( $P < .001$ ), and

higher respiratory arousal index ( $P < .001$ ). Posthoc analyses revealed a difference between all of the oximetry score groups except 2 and 3, but these 2 scores were kept separate because of differences in postoperative complication rates. Oximetry score was significantly associated with an increasing proportion of subjects who required intervention for respiratory compromise in the postoperative period ( $P < .01$ , Fisher's exact test). A positive oximetry (score 2–4) detected 9 (82%) of 11 children who required major intervention for respiratory compromise (Table 2). The missed cases both were boys, aged 20 and 22 months, with preoperative AHIs of 5.0 and 8.3 events/hour, respectively, on preoperative PSG without desaturation <90%. Both required brief bag-and-mask ventilation on emergence from anesthesia. One boy required oxygen in the recovery room, but no other interventions were required in either case after that time. The positive predictive value of oximetry for major respiratory compromise was 10% (9 of 86).

### Phase 3: Prospective Evaluation of the Score

A total of 230 children (39% female; 65% white; median age: 4.3 years) had overnight oximetry as a first test for suspected OSA in 12 months. Eighty percent of parents reported that their children had no other medical problems. Reported medical problems included asthma or other chronic lung disease (12), Down syndrome (3), obesity (3), developmental delay (8), and other significant medical condition (9). The outcome after oximetry testing could not be determined in 7 cases (4 girls; median age: 4.4 years), and these were excluded from additional analyses. All 7 had normal/inconclusive oximetry (category 1).

The oximetry study was technically unsatisfactory in 8 (3.5%) cases, because <6 hours were recorded before disconnection of the oximeter (5 of 8 [63%] were younger than 3 years, compared with 30% of the whole group ( $P = .06$ , Fisher's exact test). Oximetry was repeated in 4 cases within 1 month of the

TABLE 2. Phase 2 Sleep Study Parameters, by McGill Oximetry Score

	Oximetry Score				P Value
	1 (n = 69)	2 (n = 38)	3 (n = 23)	4 (n = 25)	
AHI (n/h)					
Mean	4.1	12.6	13.3	39.9	<.001*
95% CI	3.0–5.1	9.1–16.0	8.5–18.1	26.5–53.3	
Desaturation index (n/h)					
Mean	2.4	8.6	11.4	40.0	<.001*
95% CI	1.8–2.9	6.2–10.9	7.8–15.1	26.3–53.7	
Lowest SaO <sub>2</sub> (%)					
Mean	89.6	83.2	80.9	59.2	<.001*
95% CI	88.6–90.5	80.9–85.4	77.7–84.2	54.3–64.1	
Respiratory arousal index (n/h)					
Mean	1.9	6.3	8.8	22.0	<.001*
95% CI	1.4–2.3	4.4–8.2	5.2–12.5	12.8–31.3	
Major intervention for respiratory compromise (n [%])	2 (3%)	2 (5%)	2 (9%)	5 (20%)	<.04†

CI indicates confidence interval.

\* Kruskal-Wallis analysis of variance with posthoc analyses using Dunnett's C test demonstrated significant differences among results of all measures between scores 1, 2/3, and 4.

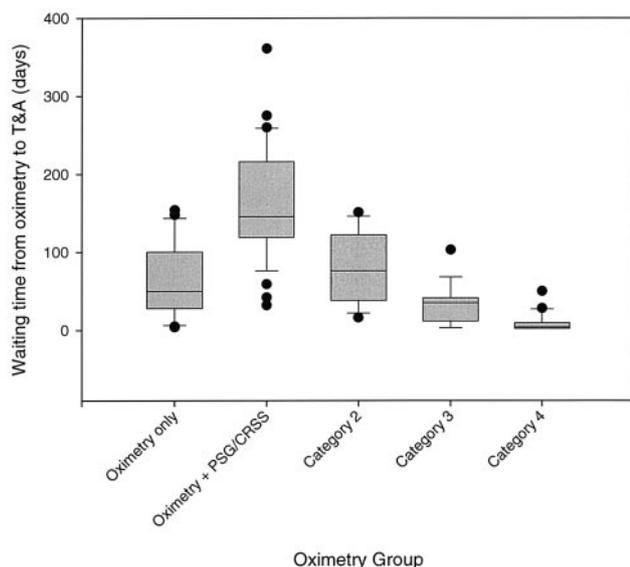
† Fisher's exact test.

first test; all were successful, and 1 patient had a positive result (category 2). Including these repeated tests, the oximetry was considered to be positive for OSA (score 2, 3, or 4) in a total of 51 (22%) of 230 cases. These patients were referred directly for consideration of T&A without additional testing. Those with a normal or inconclusive oximetry (category 1,  $n = 172$ ) or technically unsatisfactory oximetry ( $n = 7$ ) were recommended to undergo a more detailed sleep study. The course of additional investigation and treatment after the oximetry was available for 223 (97%) of 230 children; all additional analysis was performed on this subset.

Of 178 of 223 children with a normal, inconclusive, or technically unsatisfactory oximetry, 119 (67%) of 178 had either a PSG (33) or a CRSS (86); a PSG or CRSS is planned for an additional 7 children. Additional testing after oximetry was refused by the referring doctor or parent in the remaining 47 (26%) of 178 children. The PSG or CRSS was diagnostic of OSA in 58 (49%) of 119 children, and these children were referred for T&A. The oximetry recorded during PSG/CRSS remained inconclusive for OSA (category 1) in all cases.

A total of 113 patients have had T&A for OSA, including 49 of 50 with a positive oximetry, 34 of 58 with a positive PSG/CRSS, and 30 of 47 in whom an inconclusive oximetry (category 1) was the only preoperative test. As envisioned at protocol development, there was an inverse relationship between the oximetry score and waiting time for surgery (Kruskal-Wallis test,  $P < .001$ ; Fig 2).

Details for the postoperative course were available



**Fig 2.** Waiting times for surgery by oximetry group. "Oximetry only" refers to those children in whom overnight oximetry was normal or inconclusive for OSA, who proceeded to have T&A without additional sleep studies. "Positive PSG/CRSS" are those children with a normal or inconclusive overnight oximetry in whom OSA was subsequently diagnosed by PSG or home CRSS. Categories 2 to 4 refer to children with positive oximetry results. Median waiting times are 86 days for oximetry only, 217 days for positive PSG/CRSS, 77 days for category 2, 36 days for category 3, and 4 days for category 4 ( $P < .001$ , Kruskal Wallis analysis of variance).

for 102 (90%) of 113 children. Postoperative respiratory compromise was significantly related to oximetry score ( $P = .003$ , Fisher's exact test; Table 3). In addition, subgroup analysis was statistically significant for both major and minor respiratory compromise; those with higher oximetry scores had a higher incidence of complications, as had been found in phase 2. The positive predictive value of oximetry for major respiratory compromise was 13% (6 of 48). A positive oximetry (categories 2–4) detected 25 of 35 (sensitivity: 71%) of those who required any intervention for respiratory compromise in the postoperative period and 6 of 7 (sensitivity: 86%) of those who had major postoperative respiratory compromise. The 1 major complication that occurred in a child with an oximetry score of 1 occurred in an otherwise healthy 3.7-year-old boy who required bag-and-mask ventilation for laryngospasm in the recovery room. He had not had a PSG/CRSS, so the severity of OSA was unknown. Eight of the 9 children who had an inconclusive oximetry and went on to have minor postoperative respiratory compromise were in high-risk groups based on the literature<sup>21</sup>: 4 were younger than 3 years, 2 others had an AHI >10 events/hour, and 2 had significant comorbidity. The outstanding minor complication (required supplemental oxygen) occurred in a 4.3-year-old girl with an AHI of 7/hour.

After the 20-minute training session, the 3 test scorers ("learners") took a median time of 9 seconds per study to apply the score to the 100 oximetries (interquartile range: 2, 45 seconds; maximum: 5 minutes). Raw agreement with the score given to the oximetry recording at the time it was performed (G.M.N. or R.T.B., "experts") was 87%, 88%, and 97% for the pediatric respiratory fellow, the anesthesiology fellow, and the sleep technologist, respectively (weighted  $\kappa$ : 0.85, 0.86, and 0.97, all demonstrating almost perfect agreement<sup>20</sup>). Scores differed on a total of 27 (9.0%) of 300 occasions. Oximetry results were misclassified as positive on 10 (3.3%) of 300 occasions, as a result in all but 1 case of the misinterpretation of movement artifact by the learners. On 3 occasions, a positive oximetry was read as inconclusive (category 1) by the learners. On 14 (4.6%) of 300 occasions, the score was reported as positive by both the learners and the experts but the severity category did not agree. The learners overread the oximetry on 6 occasions and underread it on 8 but were >1 category different on only 1 occasion (category 4 by experts and category 2 by learner).

## DISCUSSION

We present the development and prospective evaluation of a scoring system for overnight oximetry testing in children with suspected OSA. The score objectifies consensus opinion as to what constitutes a mildly, moderately, or severely abnormal oximetry result. The score was correlated with the severity of OSA as measured by PSG. In our series, a positive oximetry test (categories 2–4) detected children who were at higher risk of respiratory compromise requiring intervention in the postoperative period. After implementation of our protocol, children with a

**TABLE 3.** Phase 3: Proportion of Children With Postoperative Respiratory Compromise ( $n = 102$ ), by Method of Diagnosis of OSA/McGill Oximetry Score

	OSA by History, Inconclusive Oximetry ( $n = 22$ )*	OSA by PSG/CRSS, Inconclusive Oximetry ( $n = 32$ )†	Oximetry Score 2 ( $n = 17$ )	Oximetry Score 3 ( $n = 10$ )	Oximetry Score 4 ( $n = 21$ )	<i>P</i> Value
Major respiratory compromise ( $n$ [%])	1 (5%)	0	1 (6%)	0	5 (24%)	.01
Minor respiratory compromise ( $n$ [%])	3 (14%)	6 (19%)	5 (29%)	6 (60%)	8 (38%)	.05
Any respiratory compromise ( $n$ [%])	4 (18%)	6 (19%)	6 (35%)	6 (60%)	13 (62%)	.003

\* Children with a normal/inconclusive oximetry in whom the PSG/CRSS was cancelled are in this group.

† Children with a normal/inconclusive oximetry who went on to have a positive PSG/CRSS are in this group.

positive overnight oximetry waited less time for surgery than those who had to wait for a more complex evaluation of breathing during sleep. The greatest benefit of this oximetry-based protocol—surgical intervention with minimal delay—accrued to those with the most severe impairment of oxygenation during sleep.

The preoperative overnight SaO<sub>2</sub> nadir has been associated with an increased risk of postoperative respiratory compromise.<sup>19,21,22</sup> The proposed score has 3 main advantages over a simple SaO<sub>2</sub> nadir as a preoperative test: 1) our score is based on previous work showing that oximetry can have a high positive predictive value for OSA,<sup>14</sup> 2) a single fall in SaO<sub>2</sub> may be seen during sleep in normal children in association with a central apnea<sup>23</sup> and thus will be less specific for detecting desaturation as a result of OSA, and 3) the score grades the severity of abnormality based on the frequency and depth of the desaturations and thus is not an all-or-nothing test.

PSG is the most comprehensive way of quantifying ventilatory and sleep abnormalities caused by OSA and is currently the gold standard diagnostic modality.<sup>12</sup> However, many children undergo T&A for OSA on the basis of clinical history and examination findings alone. Although history and examination findings have been demonstrated to have poor specificity for OSA<sup>10</sup> and do not allow the clinician to anticipate which patients might be at highest risk of postoperative respiratory complications, many children undergo T&A for OSA without the benefit of any testing. An ideal screening test for OSA would be easy to carry out, be inexpensive, and have high positive and negative predictive values for OSA. Oximetry meets the first 2 of these criteria and has a high positive predictive value.<sup>14</sup> We believe, therefore, that it has validity and potential applications in centers where children are referred for evaluation of suspected OSA. Where PSG is not available or is likely to be significantly delayed, overnight oximetry may be used to select patients who require surgery on an expedited basis and those who require close postoperative monitoring in a center that is capable of providing emergency respiratory support after hours.

Some cautionary notes regarding the use of overnight oximetry as an abbreviated diagnostic test in the evaluation of children with suspected OSA are in order. Despite the benefits outlined above, oximetry

testing has a low negative predictive value for OSA<sup>14</sup>; children with a normal or inconclusive test may have significant OSA. An oximetry score of 1 (normal/inconclusive) therefore should not be used to reassure parents or clinicians of the absence of significant OSA. The information provided by nocturnal pulse oximetry, hemoglobin saturation, and pulse rate is far less complete than that provided by PSG. Thus, PSG should be used when a comprehensive assessment of sleep and breathing is required. The characteristics of the oximeter being used are also extremely important. An oximeter with a long averaging time will underestimate the brief desaturation events seen in children with OSA, and oximeters that are prone to movement artifact may overestimate desaturation events, especially in young children who move a lot during sleep.<sup>24</sup>

Whether it is reasonable to prioritize cases for T&A on the basis of our oximetry score depends on the face, criterion, and construct validity of the score and on interobserver repeatability. Animal studies provide experimental evidence of the adverse neural effects of recurrent brief hypoxemia, specifically, learning impairment, hyperactivity, and apoptosis in the hippocampus and cortex.<sup>25</sup> This suggests that prioritization on the basis of the frequency and severity of desaturation makes sense (ie, has face validity). The choice of 80% as a cutoff for the most severe category was based on evidence of increased risk of postoperative respiratory compromise at this level of SaO<sub>2</sub> nadir.<sup>19,21,22</sup> On retrospective analysis, increasing oximetry score was associated with increasing severity of OSA, and the score was correlated with the AHI, the respiratory arousal index, and the desaturation index as measured with more complex tests of respiration during sleep (criterion validity). The scoring system was applied quickly and accurately by scorers who were not involved in its development, suggesting that the scoring system is easy to learn and apply (high interobserver repeatability).

The question remains, however, whether the oximetry score is a good measure of surgical priority (construct validity). It is a limitation of our study that we have not attempted to measure the adverse outcome of a prolonged waiting time for T&A. It is not known whether waiting weeks to months for surgery would make a difference to morbidity or mortality in children with severe OSA, but it is feasible that it

might, given the evidence of the adverse effect of hypoxemia on the developing brain<sup>15</sup> and the known association of severe OSA with cor pulmonale, failure to thrive, and adverse neurobehavioral outcomes.<sup>3,4,26,27</sup> Proof that surgical delay affects morbidity would require a randomized, controlled trial, with the test group at an increased risk that would not be ethically justified.

### CONCLUSIONS

In this study, we validated a severity scoring system for overnight oximetry, demonstrating that it reflects the underlying severity of OSA and identifies children who are at increased risk of postoperative respiratory compromise. We show that prioritizing operative intervention on the basis of oximetry score can shorten the diagnostic and treatment process for those with more severe disease. Likewise, knowledge of oximetry results can aid clinicians in planning perioperative care. However, oximetry is inconclusive in a large number of children with suspected OSA and cannot replace PSG for the definitive diagnosis of OSA.

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