

Incidence and Risk Factors for Perioperative Adverse Respiratory Events in Children Who Are Obese

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Background: Consistent with the increasing prevalence of obesity in the United States and many countries worldwide, anesthesiologists are now presented with a greater number of adult and pediatric patients who are significantly overweight. This prospective study was designed to examine the relation between age-adjusted body mass index, preoperative comorbidities, and perioperative outcome in children.

Methods: Children aged 2–18 yr undergoing noncardiac elective procedures were classified as overweight or obese based on their age- and sex-adjusted body mass index. Information was elicited regarding patient demographics, presence of comorbidities, and anesthetic technique. Data regarding the incidence and severity of perioperative adverse events were collected prospectively.

Results: Two thousand twenty-five children comprised the sample (1,380 normal weight, 351 overweight, and 294 obese). Obese children had a significantly higher prevalence of comorbidities than nonobese children, including asthma, hypertension, sleep apnea, and type II diabetes. Furthermore, obese children had a higher incidence of difficult mask ventilation, airway obstruction, major oxygen desaturation (>10% of baseline), and overall critical respiratory adverse events. Logistic regression analysis revealed several risk factors for adverse events, including procedures involving the airway, obesity, age younger than 10 yr, and a history of obstructive sleep apnea.

Conclusions: These results suggest that children presenting for elective surgical procedures who are obese have a greater prevalence of preexisting comorbid medical conditions and an increased incidence of perioperative adverse respiratory events compared with normal-weight children. Identification and awareness of risk factors for perioperative complications will be important in optimizing the anesthetic management of these children.

THE increasing prevalence of overweight and obesity has become a significant medical and societal issue worldwide. In the United States, it is now estimated that 15.5% of children and adolescents are considered obese, a figure that represents an approximate threefold increase over the past 30 yr.¹ Furthermore, childhood obesity is associated with a number of medical comor-

bidities, including hypertension, asthma, hyperlipidemia, obstructive sleep apnea (OSA), and adulthood heart disease, and, as such, adds substantially to the current economic healthcare burden.²

Given the increasing prevalence of overweight and obesity among children in the general population, anesthesiologists are likely to see a corresponding increase in the proportion of these patients who present for anesthesia and surgery. Although studies of overweight and obese adults undergoing anesthesia and surgery have demonstrated an increased risk for aspiration and perioperative airway complications,^{3,4} there is a paucity of similar outcome data with respect to children. Two studies have been performed in children, but both were retrospective.^{5,6} This study, therefore, was designed to prospectively examine the relation between age- and sex-adjusted body mass index (BMI) and perioperative adverse respiratory events in children undergoing elective, noncardiac surgery. The goals of this study were fourfold: (1) determine the prevalence of obesity in this population of children, (2) examine the prevalence of associated comorbidities, (3) measure the incidence of perioperative adverse respiratory events, and (4) identify risk factors for these outcomes. The hypothesis to be tested is that obese children who undergo elective surgical procedures have an increased incidence of perioperative adverse respiratory events compared with nonobese children.

Materials and Methods

Approval from the University of Michigan Institutional Review Board (Ann Arbor, Michigan) and waiver of informed consent were obtained for this prospective observational study. Children aged 2–18 yr undergoing any elective surgery, with the exception of repair of a cardiac anomaly, were included in the study. A nonprobability consecutive sampling technique was used in which all obese children presenting for elective surgery were included, plus a large sample of normal and overweight children selected at random (using tables of random numbers) from the daily surgical schedule. Preoperative height and weight were used to calculate BMI using the formula $BMI = \text{weight}/\text{height}^2$. Children were then classified as obese using the method of Cole *et al.*, which uses combined international data to adjust BMI according to the age and sex of the child.^{6,7} In addition, weight, height, and age were collected on all children undergoing an elective procedure during a single 2-week

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Table 1. Definitions of Airway Events

Oxygen desaturation	
Minor	5–10% decrease from baseline
Major	>10% decrease from baseline
Coughing	
Minor	One to several coughs
Major	Continuous coughing
Breath holding	
Minor	<30 s
Major	>30 s requiring an intervention
Airway obstruction	
Minor	Corrected with repositioning or placement of an oral/nasal airway
Major	Requiring jaw–chin thrust maneuver, or placement of an LMA or ETT
Laryngospasm	Requiring continuous positive airway pressure or intervention with a muscle relaxant
Difficult mask ventilation	Difficult mask ventilation score of >3 on Han scale, ²⁴ <i>i.e.</i> , inadequate, unstable, requiring two practitioners, or inability to mask ventilate
Bronchospasm	Auscultated wheezing
Adverse respiratory event	At least one adverse respiratory event during the perioperative period
Critical respiratory adverse event	At least one major adverse respiratory event (including the occurrence of any laryngospasm or bronchospasm) during the perioperative period

ETT = endotracheal tube; LMA = laryngeal mask airway.

period to estimate the overall prevalence of obesity and overweight in our population.

The following data were collected prospectively by trained research assistants: demographics (including weight, height, and age), type and duration of anesthesia and surgery, and comorbidities. Diagnoses of comorbidities such as asthma and OSA were obtained from the history and physical and from the medical record. Data regarding the incidence and severity of respiratory adverse events were collected prospectively at five time points throughout the perioperative period (*i.e.*, induction, tracheal intubation or placement of a laryngeal mask airway, during maintenance, at emergence, and during postoperative recovery) by the anesthesia provider managing the case. Furthermore, the cumulative incidences of any single adverse respiratory event and any single major (critical) event (see table 1 for definitions) were recorded. Although none of the providers had a vested interest in the study, they were generally unblinded to the patient's BMI category. The research assistant followed up with the anesthesia care provider to ensure completeness of the documentation. Although the anesthetic management of each patient was at the discretion of the individual anesthesia provider, the providers were asked if they had modified their anesthetic plan because the child was obese.

Other adverse events, including aspiration, postoperative nausea and vomiting, and any unplanned hospital admission, were noted. Per routine practice, parents were telephoned after discharge, and data related to postoperative nausea and vomiting, surgical site appearance, and any other complications were recorded.

Statistical Analysis

Data were analyzed using SPSS[®] software (SPSS Inc., Chicago, IL). Parametric data such as age, anesthesia, and surgical times were analyzed using analysis of variance

followed by *post hoc* pairwise comparisons using Tukey or Dunnett C tests depending on equality of variances and sample size. Data are presented as mean and SD. Nonparametric data were analyzed using chi-square with Fisher exact tests (where appropriate) and are presented as n (%). Independent variables that were found by univariate analysis to be significantly associated with the dependent outcome measures were force entered into a multiple logistic regression model. *P* values less than 0.025 were accepted as statistically significant.

An *a priori* sample size was determined based on results from a previous study from our department, in which the overall incidence of adverse respiratory events in children was 24.2%.⁸ Accepting a 35% increase in adverse respiratory events in obese over nonobese children as clinically significant and given that the ratio of normal to obese children in our population is approximately 4:1, we required minimum sample sizes of 1,181 and 294, respectively ($\alpha = 0.05$, $\beta = 0.2$, two-sided). Overweight children were sampled in approximately the same proportions as the obese children.

Results

Completed data were collected from a total of 2,025 children who presented for surgery during a 20-month period (April 2004 through December 2005). Two hundred ninety-four children (14.5%) were classified as obese, 351 (17.3%) were overweight, and 1,380 (68.1%) were normal weight. The age-adjusted BMI of this sample was similar to the distribution of weight classification obtained from the separate sample of all children who underwent elective surgery over a defined 2-week period (*i.e.*, 9.5, 21.9, and 68.6%, respectively). Initial analysis of the three groups showed that the normal-weight

Table 2. Description of the Sample

	Nonobese, n = 1,731	Obese, n = 294
Male sex	966 (55.8)	181 (61.6)
Age, yr	9.17 ± 4.6	10.7 ± 4.4*
BMI, range [mean ± SD], kg/m ²	9–29.9 [17.8 ± 3.3]	19.3–62.5 [31.2 ± 8.5]
Race		
White	1,409 (81.5)	238 (81.2)
Black	165 (9.5)	35 (11.9)
Hispanic	36 (2.1)	3 (1.0)
Other	115 (6.6)	15 (5.1)
ASA physical status		
I, II	1,526 (88.2)	251 (85.4)
III, IV	204 (11.8)	43 (15.1)
Surgical service		
General surgery	263 (15.2)	34 (11.6)
Otolaryngology	106 (7.7)	16 (5.4)
Otolaryngology–airway†	229 (16.6)	51 (17.3)
Orthopedic	214 (12.4)	56 (19.0)
Urology	176 (10.2)	22 (7.5)
Ophthalmology	137 (7.9)	21 (7.1)
Other‡	389 (28.3)	83 (28.2)
Relevant medical history		
Hypertension	19 (1.1)	7 (2.4)
Asthma	292 (16.9)	83 (28.3)*
Snoring	160 (9.2)	42 (14.3)*
Sleep apnea	128 (7.4)	41 (14.0)*
Reflux	161 (9.3)	48 (16.3)*
Diabetes (type II)	2 (0.1)	8 (2.7)*
URI within 4 wk	86 (5.0)	15 (5.1)

Data are presented as n (%) or mean ± SD.

* $P \leq 0.025$ vs. nonobese group. † Otolaryngology–airway includes tonsillectomy, bronchoscopy, and other procedures involving airway manipulation. ‡ Other procedures include offsite procedures such as scans, cardiology, gastroscopic, hematology, and dental procedures.

ASA = American Society of Anesthesiologists; BMI = body mass index; URI = upper respiratory tract infection.

and overweight children were demographically similar and behaved in exactly the same way with respect to the outcomes. Therefore, for clarity of analysis and presentation, we decided to restrict our analysis to two groups only, *i.e.*, obese and nonobese (normal and overweight combined).

The demographics of the study sample are presented in table 2. There were no differences in the prevalence of upper respiratory tract infections between groups. However, children who were obese were significantly older than the nonobese children and had a significantly higher prevalence of coexisting conditions, including asthma, hypertension, OSA, gastric reflux, and type II diabetes mellitus. Table 3 presents a description of the preoperative airway assessment for each cohort and shows that obese children were less likely to be classified as Mallampati I compared with nonobese children.

The airway and anesthetic techniques used in the care of these children are presented in table 4. Tracheal intubation was successful on the first attempt in 88–90% of cases, with no differences between groups. Approximately 12% of anesthesiologists caring for obese children

Table 3. Comparison of the Preoperative Airway Assessments* between Groups

	Nonobese	Obese
Mallampati scores ²⁵		
I	1,240 (77.5)	178 (62.9)†
II	331 (20.7)	97 (34.4)
III	24 (1.5)	8 (2.8)
IV	5 (0.3)	0.0
Cormack-Lehane visualization grade view ²⁶	n = 1,633	n = 269
I	1,025 (62.8)	168 (62.5)
II	113 (6.9)	30 (11.2)
III	11 (0.7)	3 (1.1)
IV	4 (0.2)	0.0

Data are presented as n (%).

* Percentages are calculated based on the total number of children who had the assessment(s) performed, which did not include the entire sample. † $P < 0.001$ compared with nonobese group.

reported an *a priori* change in their anesthetic plan because of the child's obesity. There was, however, no difference in the incidence of critical respiratory adverse events between those who had specifically changed their plan and those who had not (51.6% vs. 38.6%, respectively). Induction of anesthesia *via* the intravenous route, use of muscle relaxants, and controlled ventilation were more commonly used in obese children compared with the nonobese. When controlling for these variables, the incidence of critical respiratory adverse events was greater in the obese group compared with the nonobese group: controlled ventilation (odds ratio [95% confidence interval]: 2.25 [1.52–3.34]; $P < 0.01$), muscle relaxant (2.45 [1.54–3.89]; $P < 0.01$), and intravenous anesthesia (2.49 [1.59–3.9]; $P < 0.01$).

Table 5 compares the incidence of all perioperative respiratory adverse events between obese and nonobese

Table 4. Comparison of Anesthetic Care between Groups

	Nonobese	Obese
Induction method		
Facemask	1,274 (74.4)	171 (58.6)*
Intravenous	438 (25.6)	121 (41.4)*
Induction agent		
Sevoflurane	1,206 (70.3)	158 (54.7)*
Propofol	510 (29.7)	131 (45.3)*
Rapid sequence induction	26 (1.5)	17 (5.8)*
Use of muscle relaxant	408 (23.6)	103 (35.0)*
Maintenance method		
Facemask	111 (6.4)	15 (5.1)
Laryngeal mask airway	431 (24.9)	72 (24.6)
Endotracheal intubation	1,159 (67.0)	203 (69.3)
Maintenance agent		
Sevoflurane	171 (11.1)	41 (16.6)
Isoflurane	1,364 (88.9)	206 (83.4)
Controlled ventilation	642 (37.3)	135 (46.2)*
Use of intubating equipment†	40 (3.6)	7 (3.5)
Duration of anesthesia, min	100.1 ± 78.8	105.7 ± 81.1

Data are presented as n (%) or mean ± SD.

* $P \leq 0.025$ compared with nonobese group. † Special equipment includes fiberoptic scope, light wand, bougie, other.

Table 5. Comparison of Perioperative Respiratory Adverse Events between Obese and Nonobese Children

	Nonobese	Obese	OR (95% CI)
Difficult mask ventilation	34 (2.1)	24 (8.7)	4.5 (2.6–7.7)*
Coughing—major	74 (4.3)	21 (7.1)	2.0 (1.4–2.8)†
Breath holding—major	27 (1.6)	5 (1.7)	1.1 (0.4–2.9)
Airway obstruction—major	193 (11.2)	55 (18.9)	1.8 (1.3–2.6)*
Laryngospasm	75 (4.3)	14 (4.8)	1.1 (0.6–1.9)
Bronchospasm	34 (2.0)	18 (6.1)	3.3 (1.8–5.8)*
Oxygen desaturation—major	155 (9.1)	48 (16.8)	1.8 (1.4–2.5)*
Overall airway event‡	1,027 (59.3)	213 (72.4)	1.8 (1.4–2.4)*
Critical airway event§	435 (25.1)	117 (39.8)	1.9 (1.5–2.5)*
Minutes to incision	23.3 ± 16.9	25.7 ± 19.6†	
Minutes to arousal	28.8 ± 31.8	20 ± 65.3*	
PACU duration of stay	107 ± 57.0	102.9 ± 59	
Discharge disposition			
Home	1,280 (74.3)	211 (72.3)	0.9 (0.7–1.2)
General care	393 (22.8)	71 (24.3)	1.1 (0.8–1.5)
Intensive/moderate care	50 (2.9)	10 (3.4)	1.1 (0.6–2.3)
Unanticipated hospital admission	38 (2.2)	4 (1.4)	0.6 (0.2–1.7)

Data are presented as n (%) or mean ± SD.

* $P = 0.001$. † $P < 0.05$. ‡ At least one respiratory event at any time point. § At least one major respiratory event at any time point.

CI = confidence interval; OR = odds ratio; PACU = postoperative anesthesia care unit.

children. There was an increased incidence of critical respiratory adverse events among the obese children. This observation was maintained when controlling for surgery involving the airway (odds ratio [95% confidence interval]: 1.32 [1.03–1.69]; $P < 0.01$), history of asthma (1.61 [1.22–2.15]; $P < 0.01$), OSA (1.25 [0.94–1.67]; $P < 0.01$), and age younger than 10 yr (1.98 [1.37–2.89]; $P < 0.01$).

Exploratory univariate analysis identified several factors that were associated with overall critical respiratory adverse events (table 6). These included asthma, obesity, age, tracheal intubation, procedures involving the airway, and histories of asthma, snoring, or OSA. Correlations between these variables were examined using the Spearman rank correlation coefficient. Moderate corre-

Table 6. Odds Ratios and 95% Confidence Intervals for the Risk Factors Associated with Critical Perioperative Adverse Respiratory Events

	OR (95% CI)	
	Univariate	Multivariate
Obesity	1.97 (1.52–2.55)*	2.0 (1.6–2.7)†
Surgery of the airway	3.35 (2.62–4.29)*	2.2 (1.6–2.9)†
Age < 10 yr	1.98 (1.60–2.44)*	1.8 (1.5–2.3)†
Hx of asthma	1.48 (1.16–1.88)*	1.3 (0.98–1.6)‡
Hx of OSA	3.54 (2.57–4.87)*	1.6 (1.1–2.4)†
Hx of URI within 4 wk	1.26 (0.92–1.93)	
Hx of snoring	2.85 (2.11–3.83)*	
Induction: facemask	1.6 (1.28–2.02)*	
Endotracheal intubation	1.48 (1.19–1.85)*	
Use of muscle relaxant	0.81 (0.65–1.02)	
Controlled ventilation	1.18 (0.97–1.31)	
Maintenance: isoflurane	1.25 (0.89–1.74)	

* $P < 0.01$. † $P < 0.02$, Wald test. ‡ $P = 0.076$, Wald test.

CI = confidence interval; ETT = endotracheal tube; Hx = history; LMA = laryngeal mask airway; OR = odds ratio; OSA = obstructive sleep apnea; URI = upper respiratory tract infection.

lation was observed between OSA and snoring ($\rho = 0.45$; $P < 0.001$); however, analysis revealed only low correlations (< 0.15) between the other variables. Factors from the univariate analyses were subsequently forced into a logistic regression model, which yielded five independent risk factors for critical respiratory adverse events in this surgical population of children (table 6).

Four children, all in the nonobese group, experienced apparent aspiration intraoperatively but did not require treatment beyond suctioning of the oropharynx. Seven children vomited during induction of anesthesia (six in the nonobese group and one in the obese group); however, none developed adverse sequelae. There were no differences in the incidence of postoperative vomiting between the nonobese and obese groups (8.3% and 7.9%, respectively). Three children (all in the nonobese group) were noted to have grade 1 pressure sores in the recovery area. Four hundred sixty-two children (22.3%) were telephoned by the recovery room staff after surgery. The proportions of obese and nonobese children who were contacted were the same (21.8% and 22.9%, respectively). There were no differences in parent report of surgical site problems between the nonobese and obese groups (2.3% and 3.1%, respectively) or return to activity/ambulation (69.0% and 75.4%). However, children who were obese had less nausea and vomiting at home compared with the nonobese group (4.8% vs. 16.8%; $P = 0.013$). One child in the nonobese group returned to the emergency department after discharge home due to prolonged vomiting.

Discussion

Given the increasing national and international upward trends in the incidence of obesity¹ and the fact that

obese individuals are more likely to experience health-related problems, anesthesiologists are now presented with an increasing proportion of adult and pediatric patients who are overweight or obese. This observation is further evidenced by the increasing number of adults and even adolescents who are opting for bariatric corrective surgery⁹ and is reflected in the results of our study wherein 32% of children presenting for anesthesia and surgery were overweight or obese. These results are consistent with national trends and are also similar to results from a recent retrospective audit in children.^{1,5} As such, they lend some external validity to our findings.

Although the definition of adult obesity based on BMI (30 kg/m²) is well established, there is no universally accepted criterion for use in children. This is partly because childhood BMI changes significantly as a function of age and sex. The Centers for Disease Control and Prevention criteria¹⁰ define overweight in children as BMI of greater than 85th to less than 95th percentile and obese as 95th percentile or greater, but some would argue that these cutoffs are too arbitrary and may not reflect the age-related changes in BMI that occur during childhood. In response to this, Cole *et al.*⁷ constructed age- and sex-specific centile curves based on BMI data from 192,727 children from six countries. Age- and sex-specific cutoffs for obesity were then defined as those on or above the BMI curve, which passes through the 30-kg/m² point at age 18 yr. This approach, therefore, provides internationally relevant data that corrects BMI for age and sex and links it to the current accepted definition of adult obesity.^{6,11}

Childhood obesity is associated with a number of important medical comorbidities, including type II diabetes, asthma, OSA, hyperlipidemia, hypertension, and heart disease.¹²⁻¹⁸ In our study, obese children were more likely to present with histories of hypertension, OSA, asthma, snoring, reflux, and type II diabetes mellitus. Chung *et al.*³ identified several preexisting medical conditions as predictors of adverse events in patients undergoing elective surgery, including obesity, hypertension, asthma, smoking history, and gastroesophageal reflux. Consistent with these results, our study identified obesity and a history of OSA as independent predictors of perioperative critical adverse respiratory events in children.

Most adult studies have shown that overweight and obesity are risk factors for perioperative adverse events, including difficult mask ventilation,^{4,19} laryngoscopy,^{20,21} aspiration, postoperative atelectasis,²² and surgical site infection.²³ However, despite the adult data, there is a paucity of information regarding outcome in overweight or obese children who present for anesthesia and surgery. In one recent retrospective study, there was a small increase in minor respiratory complications in children who were obese.⁶ Compared with normal-weight children, those who were obese had a significantly greater

risk of intraoperative oxygen desaturation (2% *vs.* 0.19%, respectively) and unexpected hospitalization (2% *vs.* 0.19%). In another database audit study, Nafiu *et al.*⁵ showed that compared with normal-weight children, obese children had a greater frequency of difficult mask ventilation (7.4% *vs.* 2.2%, respectively), difficult laryngoscopy (1.3% *vs.* 0.4%), and postoperative airway obstruction (1.6% *vs.* 0.07%). Consistent with these studies, our study revealed that children who were obese had a greater incidence of difficult mask ventilation, airway obstruction, bronchospasm, major oxygen desaturation, and overall critical respiratory events. Our study, however, demonstrated no association between obesity and difficult laryngoscopy. Indeed, tracheal intubation was deemed equally successful on the first attempt regardless of BMI. Although the results of these other pediatric studies were similar to ours in terms of trends, one should note that the absolute frequencies of adverse events were significantly lower than ours. The reasons for this are unclear but may reflect differences in study design particularly with respect to the potential for underreporting that can occur when analyzing retrospective data.

A few points regarding the limitations of this study deserve mention. First, this is a nonrandomized, nonblinded study and, as such, there is some potential for selection and/or observer bias. However, despite this, we believe that any effect would be minimized by the large sample size and the fact that all data were collected by individuals with no vested interest in the study's outcome. We also recognize that because the determination of sample size was based on expected differences in the incidence of critical perioperative adverse events between normal-weight and obese children, the sample may not have been sufficiently powered to detect differences in all individual univariate and multivariate comparisons.

To our knowledge, this is the first large-scale prospective study examining the effect of overweight and obesity on perioperative outcome in children undergoing elective noncardiac surgery. Results of this study confirm the observed upward trend in the prevalence of overweight and obesity among children presenting for anesthesia and surgery. Furthermore, these results support our hypothesis that the incidence of perioperative adverse respiratory events is increased in children who are obese. Although all adverse respiratory events were easily managed and there were no serious sequelae, identification of risk factors will be important as a means to anticipate, recognize, and treat complications that may disproportionately occur in obese children, and thus optimize their anesthetic care.

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