Child obesity and anaesthetic morbidity
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Current Opinion in Anaesthesiology 2008, 21:308–312

Introduction
A worldwide increase in the prevalence of obesity has been observed recently in both developed and developing countries [1]. For example, the annual absolute changes in the prevalence of obesity in children between 1985 and 2004 are estimated to be 1.7% in Australia, 0.8% in the US, 0.5% in the UK, 0.5% in China and 0.4% in Brazil [2]. In western Europe, 15–20% of children and adolescents are obese. The idiom ‘pandemia of the new millennium’ is used in the paediatric and obesity literature. Moreover, children who are overweight are more likely to continue to gain weight and to become overweight or obese adolescents and obese adults. Last, they already present with manifestations of the comorbidities associated with adult obesity.

Little anaesthetic literature has been devoted so far to this topic, and most data are inferred from what is known about the anaesthetic management of obese adults [3–5]. From the anaesthesiologist’s point of view, caring for an obese child or adolescent means dealing with early manifestations of the comorbidities of adult obesity and sometimes for new surgical procedures (bariatric surgery).

Definitions
The body mass index (BMI = kg \( \div \) m\(^2\)) is used to quantify overweight in adults; a BMI of 25 or more means overweight; 30 or more, obesity; and 40 or more, morbid obesity. BMI, however, cannot be used as such in paediatric patients because of growth and differences in the distribution of fat and muscles, body shape or bone density occurring at puberty. Therefore, specific growth curves showing the percentiles for BMI according to age and sex have been established [3,5].

Two sets of curves are used. The first uses representative data from the US (website: www.cdc.gov/nchs/data/nhanes/growthcharts/set3chart%2016.pdf) and according to it

(1) a BMI of more than percentile 85 of the BMI at the child’s age means overweight;
(2) a BMI of more than percentile 95 means obesity;
(3) a BMI of more than percentile 99 means super obesity.

The second aims more at defining internationally valid cut-off points for BMI by extrapolating down to childhood the curves corresponding to a BMI of 25 or 30 at 18 years of age [6]. The results are somewhat different; for example, a boy is obese if his BMI is over 19.5 vs. 20.6 at 7 years of age or over 25.5 vs. 27.6 at 14 years.

The following definitions are often referred to in the literature:

(1) Total body weight (TBW) is the patient’s actual body weight.
(2) Lean body weight (LBW): On the contrary to what is thought, an obese patient is not a thin patient covered with a sort of fatty coat. In reality, both adipose tissue...
and LBW are increased in obese patients and LBW it is usually only 20–40% less than TBW.

(3) Ideal body weight (IBW): In 1–18-year-old patients, IBW can be calculated from

\[ \text{kg} = \text{height (cm)}^2 \times 1.65/1000 \]

### Causes of obesity

In over 90% of the cases, overweight and obesity are caused by the combination of consuming too many calories (increased fat content in foods, high calorie drinks) and not having enough physical activities (watching TV). Environmental and genetic factors (leptin deficiency) probably play a minor role, but in rich countries, obesity is usually more prevalent in lower income social categories [3,5].

In approximately 5% of the cases, however, a medical cause of obesity can be identified as

1. a syndrome: Prader–Willi syndrome beyond infancy, Laurence–Moon–Biedl syndrome
2. some inborn errors of metabolism necessitating a hypercaloric diet to prevent hypoglycaemia (e.g. glycogen storage diseases) or protein catabolism
3. iatrogenicity: high-dose steroid therapy such as in paediatric haematology and oncology, nephrotic syndrome and others
4. or inability to move, for example, late stage Duchenne’s muscular dystrophy.

### Pathophysiology

Adipose tissue has for long been considered as a passive stocking area for fat [7]. It is presently known to be a complex endocrine system communicating with the brain and peripheral tissues by releasing leptin and adipokynins proteins such as C-reactive protein (CRP), interleukin (IL)-6, tumour necrosis factor α (TNFα), lipoprotein-lipase, renin, adiponectin, etc. Its malfunction leads first to resistance to insulin and then to the metabolic syndrome (i.e. central obesity, hyperinsulinaemia, systemic hypertension and hypertriglyceridaemia). Obesity can, in fact, be considered as a chronic inflammatory state.

Obese paediatric patients show the following early manifestations of the comorbidities found in adult obesity.

### Respiratory

The incidence of asthma, especially exercise-induced asthma, is increased and is prevalent in up to 30% of overweight children [3,5]. In case of obesity, a restrictive pattern is also present; chest wall compliance decreases along with functional residual capacity (FRC), vital capacity and inspiratory capacity. This increases the work of breathing and the risk of atelectasis as the lung closing volume falls within tidal ventilation, further leading to chronic hypoxemia in case of severe obesity.

Sleep apnoea disorders (i.e. recurrent episodes of partial or complete airway obstruction during sleep) are present in at least 17% of obese children. Both increased visceral fat favouring airway collapse and increased pharyngeal fat decreasing the upper airway caliber contribute to it. Obstructive sleep apnoea induces chronic nocturnal hypoxaemia and leads progressively to pulmonary hypertension and cor pulmonale. Moreover, daytime sleepiness increases physical inactivity.

### Cardiovascular

The prevalence of systemic hypertension increases with BMI. Obese children have an increased heart rate (HR) and blood pressure (BP) because their sympathetic nervous system is overactive. Moreover, as adipose tissue is well vascularized, an increased cardiac output (grossly 0.11/min for each kg of excess adipose tissue) and blood volume is observed. As a consequence, left ventricular (LV) hypertrophy develops early but is reversible with weight loss. In severely obese adolescents, increased oxygen consumption increases the workload of the heart and they are at risk of myocardial strain.

### Endocrine

Resistance to insulin and the metabolic syndrome is present in 39% of moderately obese and in 50% of severely obese adolescents [8]. CRP and IL-6 levels rise with the degree of obesity, whereas those of adiponectin, a biomarker of insulin insensivity, decrease. These proteins are also potential predictors of adverse cardiovascular effects caused by atheromatosis. Diabetes type 2 develops rapidly once the metabolic syndrome is present.

### Gastrointestinal

Due to the increased abdominal mass, gastroesophageal reflux disease is frequent. Regarding gastric emptying time, studies show conflicting results; some show a delayed gastric emptying time whereas others show no difference as compared with nonobese patients.

Nonalcoholic fatty liver disease (NAFLD) is present in 50–60% of obese children [3,9] and is probably the most common form of chronic liver disease in children in the US. Histologically, it progresses from hepatic steatosis (abnormal accumulation of fat in hepatocytes) to fibrosis. Due to unknown genetic and/or environmental risk factors, nonalcoholic acute steatohepatitis (NASH) can also occur, and a few cases of cirrhosis have been described. NAFLD is often asymptomatic; increased serum alanine aminotransferase (ALT) is present only in severe cases, and ultrasound examination is the most
reliable way to screen it. Both steatosis and NASH may get resolved with weight reduction.

**Psychology**

Some form of depression with a poor body image and loss of self-esteem are often present in obese paediatric patients. The relationship with lean peers is poor (teasing, marginalization).

Some pathologies specific to the paediatric age group are

1. slipped capital femoral epiphysis;
2. tibia vara (Blount disease): repetitive trauma from overweight on the medial tibial growth plate results in growth plate suppression and varus deformity of the tibia;
3. cholelithiasis, because bile is supersaturated with cholesterol;
4. polycystic ovary syndrome with clinical signs of hyperandrogenism (hirsutism, irregular menses);
5. idiopathic intracranial hypertension (pseudotumour cerebri), probably caused by increased intrathoracic pressure, decreasing venous outflow from the head.

**Pharmacology**

The adequate dosage of anaesthetic drugs is difficult to guess in an obese patient; theoretically, lipophilic drugs have an increased volume of distribution, and the pharmacology of hydrophilic drugs remains unchanged. Literature on adults, however, shows that it is not always true and there are conflicting results [3,10]. Moreover, little is known about protein binding and metabolization, although renal clearance is generally increased.

As a rule of thumb, the initial dose should be calculated according to the patient’s IBW, and titrated to effect. Regarding thiopental and midazolam, the distribution volume of which is increased in obese adults, an increased duration of action should be expected if dosage is made according to TBW. The dosage of succinylcholine should be calculated according to TBW. If sevoflurane is used, an increased production of F- is observed but no nephrotoxicity has been reported. Desflurane is considered the best choice for maintenance in obese patients.

**Medical and surgical treatment of obesity**

As behavioural weight management alone is poorly effective in managing severe overweight or obesity, medical or surgical treatments are often proposed.

**Medical treatment**

The following drugs are sometimes prescribed to obtain some weight loss:

1. Orlistat decreases the bowel absorption of triglycerides present in food by 30%.
2. Sibutramine has an anorexigen effect by inhibiting the reuptake of noradrenaline and serotonin; drug interactions are thus possible (e.g. with tramadol).
3. Rimonabant blocks the cellular cannabinoid receptor 1 in the brain, bowel and adipose tissue. Its use in paediatric patients is not allowed by the Food and Drug Administration (FDA).
4. Metformin is used in case of diabetes type 2.

**Bariatric surgery**

As medical treatment often fails, surgery is increasingly proposed to produce weight loss because it may reverse the metabolic and psychosocial consequences of obesity in adolescence [5,11].

Two main types of procedures exist:

1. Restrictive surgery such as placing an adjustable gastric band (lap band) around the upper end of the stomach to create a small gastric pouch, and a restrictive stoma to slow the passage of food into the distal gastrointestinal tract. The surgery fails if the patient starts eating large amounts of liquid food (ice cream).
2. Restrictive and malabsorptive surgery: a Roux-en-Y loop is used to create a small gastric pouch and bypass part off the small bowel. Early complications are not uncommon (infection, stricture, Anastomotic leak, etc.), and there is a great risk of postoperative dumping syndrome. Moreover, the nutritional and metabolic consequences of malabsorption (iron, folate, vitamin B1, B2, B6 B12 deficiency, calcium and vitamin D deficiency) require a long-term follow-up and micro-nutrient supplementation to prevent those deficits.

Both surgeries can be performed under laparoscopy.

**Anaesthetic management**

Most data on the perianesthetic care of obese paediatric patients are inferred from the literature on the anaesthetic management of obese adults [3–5]. They are summarized hereafter.

**Preoperative examination**

A careful history should be taken regarding

1. symptoms of sleep apnoea: snoring, bad sleep with frequent awakening, day-time sleepiness;
2. tolerance to exercise: breathlessness, asthma;
3. recent weight loss or gain;
4. medications, including herbs or special mixtures, taken to lose weight which can interfere with anaesthesia or haemostasis.
In addition to the standard physical examination done before any anaesthesia, a BMI percentile chart should be used to know whether the patient is overweight or obese. In case of obesity, transcutaneous haemoglobin saturation (SpO₂) during breathing room air should be documented, and fasting blood glucose, night oximetry (if symptoms of sleep apnoea) and echocardiography (if hypertension is present) should be checked.

The same rules for preoperative fasting should be applied as in the nonobese population. In case of gastroesophageal reflux disease, the patient’s usual antireflux therapy should be administered.

**Induction and maintenance**

Room SpO₂ should be checked again in order to obtain an individualized target value for postoperative values. Difficult venous access should be foreseen. Inhalation induction is possible but is often longer and difficult due to ventilation–perfusion (V/Q) mismatch, intermittent airway obstruction and difficult mask fit.

Controlled ventilation via a tracheal tube is the best way to protect the airway and provide adequate ventilation; no data have been published so far on the use of the Proseal LMA (LMA Deutschland GmbH, Bonn, Germany) in obese patients but it remains a safe option in case of difficult intubation–difficult ventilation situation.

In order to lessen the risk of hypoxaemia during apnoea, careful preoxygenation should be undertaken; a 25° head-up position makes breathing easier and reduces abdominal pressure on the diaphragm, and at least 3 min of tidal breathing with 100% oxygen is necessary [3]. The best way to check adequacy of preoxygenation is to obtain an end-tidal oxygen concentration of more than 90% [12]. Whether rapid sequence induction (RSI) is mandatory in elective cases is a controversial issue, and many teams do not use it (or use a modified RSI) on the basis of a lack of evidence base of its usefulness [13]. It should, however, be kept in mind that both mask ventilation and intubation can be difficult, and that gastric inflation increases the risk of regurgitation.

Adequate equipment should be used to measure the BP. In case of invasive surgery, it is worth inserting an arterial catheter to measure it precisely and to be able to check blood gases.

Due to the V/Q mismatch, E₇CO₂ is not very reliable to evaluated PaCO₂; either blood gases or a transcutaneous measure of PaCO₂ (e.g., Tosca, Linde Medical Sensors AG, Basel, Switzerland) [14] can be used. Controlled ventilation with some positive end expiratory pressure (PEEP) is useful to catch up some FRC and prevent atelectasis, but excessive PEEP is poorly tolerated from the haemodynamic point of view.

If the patient is operated upon in the supine position, a head-up positioning (25–30°) should be obtained from the surgeon to improve ventilation; the head-down position is often poorly tolerated.

**Emergence and postoperative care**

The patient should be extubated awake and in a head-up position. Some continuous positive airway pressure (CPAP) should be provided in the postanaesthesia care unit (PACU) as well as in the ward later. Although no firm recommendations have been published, there is an increased risk of peripheral venous thrombosis, and thromboprophylaxis should be prescribed.

**Pain management**

If intravenous patient-controlled analgesia is used, the initial dosage of morphine should be calculated according to IBW and reduced further by 25%. It should be adapted later according to the patient’s response.

Regarding locoregional anaesthesia, the volume of the epidural space is probably reduced because of increased intraabdominal pressure and possibly because of increased venous return through Batson’s plexus; the initial volume of locoregional anaesthesia to be administered epidurally should be calculated according to LBW.

**Anaesthetic morbidity**

Two retrospective series have been published so far. In 100 obese children out of a series of 1133 children less than 12 years of age undergoing outpatient dental procedures, the obese children had a higher incidence of intraoperative desaturation (SpO₂ <85%) (2% vs. 0.19%) and unexpected overnight hospitalization because of postoperative desaturation than nonobese children [15].

In another series of 6094 patients [16] (mean age, 11.9 ± 5.2 years) out of whom 14.4 and 17.2% were overweight and obese, respectively,

- (1) the prevalence of diabetes type 2, hypertension and asthma was higher in obese and overweight patients than in their nonoverweight peers;
- (2) difficult airway and laryngoscopy was more common in obese children;
- (3) obese and overweight patients stayed longer in the PACU because of upper airway obstruction.

These data suggest that, although rare, perioperative respiratory events are more frequent in overweight and
obese patients; prospective studies are needed to confirm it.

**Conclusion**

Obesity is not rare in paediatric patients and we should introduce the use of BMI charts in our preoperative assessment to identify such patients and adapt our perioperative management accordingly. In obese children, perioperative morbidity is mainly related to airway and ventilation.

**References and recommended reading**

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 418).


A retrospective study of over 6000 patients, to be read before setting up a prospective study on perioperative morbidity in overweight and obese paediatric patients.
Childhood obesity and anesthetic morbidity

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Summary

Background: Obesity is present in a significant proportion of children presenting for anesthesia. Although it is perceived that obese adults have more frequent complications, the incidence of complications in obese children is unknown. Because of anticipated difficulties with mask ventilation, anesthesia is most frequently induced intravenously in obese adults, whereas inhalation induction is usually preferred in uncooperative children with few visible veins. The purpose of this study was to examine and compare anesthetic related complications in obese children undergoing dental surgery with a similar group of nonobese individuals.

Methods: The charts of 1133 American Society of Anesthesiology (ASA) physical status I and II children less than 12 years old who underwent general anesthesia for dental outpatient procedures in 2003 were retrospectively examined for patient height, weight, preoperative evaluation, anesthetic course and postoperative course. Body mass index was calculated and compared with international normative data to identify those children who were obese. Method of induction and perioperative complications were noted.

Results: A total of 100 obese and 1033 nonobese children were identified. Demographically the two groups were comparable. Inhalation induction was used in the vast majority of obese (99%) and nonobese (99.7%) patients. Overall complication rate was low. Minor respiratory complications were more frequently noted in the obese group. These consisted primarily of a higher incidence of intraoperative oxygen desaturation (2% vs 0.19%) and higher requirements for unexpected overnight hospitalization (2% vs 0.19%). The only complication related directly to inhalation induction was noted in a nonobese child who vomited and aspirated on induction.

Conclusions: Our study demonstrated a small increase in minor respiratory complications in obese children who underwent anesthesia. Inhalation induction was not associated with an increase in adverse events in this population.

Keywords: anesthesia; dental; obesity; complications; children
Introduction

The prevalence of obesity among children has tripled in the last 20 years, paralleling the epidemic increase among adults worldwide (1). This problem which affected only 4% of school age children as recently as four decades ago, now impacts on the lives of more than 16% of school age children in the USA and has become a major international pediatric health concern (2–6). Reflecting the trends in the general population, obese children now represent an increasing proportion of our elective surgical population.

Obese adults undergoing anesthesia have been demonstrated to have a higher risk of perioperative respiratory complications (7) and are also perceived to be at increased risk of regurgitation and aspiration. Primarily because of these respiratory concerns, the induction of general anesthesia in the obese adult is often different than in the nonobese counterpart. Most frequently, if the airway is perceived to be normal, anesthesia is induced with an intravenous agent and a rapid onset, short-acting relaxant following adequate preoxygenation (rapid-sequence induction). Alternatively, an awake fiberoptic intubation is performed if difficult airway management is anticipated (8).

Employing both these techniques is more difficult in the obese, frightened, uncooperative child undergoing elective surgery and an inhalation induction is commonly used. The purpose of this study was to determine whether overall anesthesia complications are more common in obese than nonobese children and to ascertain whether inhalation induction is suitable in these patients.

Methodology

Following institutional review board approval, a database of all children between the ages of 2 and 12 years who received general anesthesia for elective dental outpatient procedures in 2003 (January 1 to December 31) was identified and the charts retrospectively reviewed. The patient’s American Society of Anesthesiologists (ASA) physical status, as assigned by the anesthesiologist of record, was noted and only patients with physical status I and II were retained in the study, for a total of 1133 records. Dental procedures were chosen to be studied because the systemic physiological impact of the procedure itself was minimal, and the majority of adverse events would be related to the anesthesia. All anesthesia care was given by full time pediatric anesthesiologists working in a dedicated children’s hospital. Children cared for were from a large referral area of south Texas and reflected an ethnically diverse population.

Height and weight data from the preoperative anesthesia evaluations were recorded and body mass index (BMI) was calculated from the formula $BMI = \frac{\text{weight in kg}}{\text{height in meters}^2}$ to determine whether the child was obese. We based our definition of obesity on the combined international database, collected by Cole et al., of BMI at various ages (2). As defined by these authors, the cut off curve for obesity for each age group is patient BMI on, or above, the BMI curve which passes through the $30 \, \text{kg}\,\text{m}^{-2}$ point at age 18. Although a BMI of 30 commonly defines obesity in adults, the BMI which defines obesity in the pediatric population widely varies by age.

Additionally, information from the preanesthetic visit regarding coexisting diseases and preoperative respiratory illnesses, including the presence of an upper respiratory tract infection (URI) or a history of reactive airway disease (RAD) within the past year was collected. URI was considered to be present if the parents stated that the child had cold symptoms (runny nose, cough) or if the admitting nurse noted signs on physical examination. RAD was considered to be present if the child had a history of asthma or had used inhaled bronchodilators within the past year. No attempt was made to quantitate the severity of these preexisting conditions other than noting a positive documentation by either the admitting nurse or the anesthesiologist.

Method of anesthesia induction, maintenance, and agents used were at the discretion of the individual anesthesiologist. Data from the anesthesia record were analyzed for the method of anesthesia induction and maintenance, agents used and antiemetic prophylaxis. Intraoperative complications were noted including laryngospasm requiring therapy, vomiting, and desaturation (oxygen saturation by pulse oximetry less than 85%). Each child’s course in the postanesthesia care unit (PACU) and day surgery unit was also analyzed for postanesthesia complications, including the need for nonelective hospital or intensive care unit (ICU) admission.
supplemental oxygen requirement following emergence from anesthesia, and postoperative emesis.

Statistical analysis was performed using chi-squared tests for comparing proportions among the obese and nonobese groups (male to female ratio, proportion of ASA I and II physical status, % patients with URI symptoms, and RAD). The Student t-test was used for comparing continuous variables (age). Descriptive statistics for every age subgroup included the mean BMI and standard deviation. In addition, each data point was presented on a cumulative BMI vs age plot.

**Results**

Overall, 100 of our 1133 patients were found to be obese, for a prevalence of 8.8% in this dental population. Figures 1 and 2 show the cumulative BMI vs age data of all 1133 patients studied. Table 1 shows the average BMI for the obese and nonobese groups according to age and sex. Except for obesity and older age in the male obese vs nonobese population, the two populations were comparable (Table 2). There was no difference in preoperative respiratory illness between the groups, including recent URI and history of RAD.

Inhalation induction of anesthesia with sevoflurane was used in the large majority of patients (99% of the obese group, 99.7% of the nonobese group) and antiemetic prophylaxis, consisting of ondansetron 0.1 mg·kg⁻¹ and dexamethasone 0.1 mg·kg⁻¹, was given to 99% of both groups. Nasotracheal intubation was performed in all patients following induction of anesthesia.

Anesthetic and perioperative complications were infrequent and minor in nature for both groups as outlined in Table 3. There were two unplanned overnight hospital and ICU admissions in the nonobese group (0.19%). One was secondary to aspiration on induction and the other due to seizure-like activity postoperatively in an otherwise healthy patient with Beckwith-Wiedeman syndrome. The obese group also had two unplanned overnight hospital admissions (2%) both because of postoperative oxygen desaturation. This difference was statistically significant (P ≤ 0.01). We also found a higher incidence of intraoperative desaturation (2% vs 0.19%) among obese patients. Overall, however, the incidence of anesthesia complications was very low in both groups, and no patient was hospitalized for more than 24 h.

**Discussion**

Some degree of overweight is found in one-third of American school age children, reflecting the ever
rising incidence in the population as a whole (1). This dramatic shift in the last 30 years has been attributed to radical changes in the balance of energy intake and expenditure, with ready availability of foods high in fat and sugar content and the adoption of a more sedentary daily life style. We anticipate that unless there is a fundamental change in eating and exercise habits, the percentage of obese children in our elective surgery population will continue to increase.

The definition of obesity in adults as a BMI > 30 kg·m⁻², which correlates with total body fat in the majority of individuals, has been relatively straightforward. Defining obesity in children has been more difficult. Current Center for Disease Control (CDC) growth charts define obesity in the pediatric age group using population data from children and adolescents in the USA obtained prior to the current explosion in the number of overweight children (http://www.cdc.gov/growthcharts/) (accessed December 1, 2004). Overweight has been regarded as a BMI above the 85th percentile for age and gender, while BMI above the 95th percentile is considered obese. This 95th

### Table 1
Average BMI of obese and nonobese patients grouped by age and sex

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Nonobese males</th>
<th>Obese males</th>
<th>Nonobese females</th>
<th>Obese females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Average BMI</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>2–3</td>
<td>110</td>
<td>16.5</td>
<td>1.6</td>
<td>5</td>
</tr>
<tr>
<td>3–4</td>
<td>148</td>
<td>16.5</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td>4–5</td>
<td>139</td>
<td>16</td>
<td>1.3</td>
<td>11</td>
</tr>
<tr>
<td>5–6</td>
<td>69</td>
<td>15.9</td>
<td>1.5</td>
<td>10</td>
</tr>
<tr>
<td>6–7</td>
<td>40</td>
<td>16.3</td>
<td>1.3</td>
<td>10</td>
</tr>
<tr>
<td>7–8</td>
<td>21</td>
<td>15.9</td>
<td>1.9</td>
<td>4</td>
</tr>
<tr>
<td>8–12</td>
<td>39</td>
<td>17.7</td>
<td>2.4</td>
<td>9</td>
</tr>
</tbody>
</table>

n, number of patients; BMI, body mass index; SD, standard deviation. NA: No obese females in this age group.

### Table 2
Population characteristics of obese and nonobese children

<table>
<thead>
<tr>
<th></th>
<th>Obese (n = 100)</th>
<th>Nonobese (n = 1033)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>54 (54)</td>
<td>566 (55)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Females</td>
<td>46 (46)</td>
<td>467 (45)</td>
<td>n.s.</td>
</tr>
<tr>
<td>ASA I</td>
<td>78 (78)</td>
<td>910 (88)</td>
<td>0.01</td>
</tr>
<tr>
<td>ASA II</td>
<td>22 (22)</td>
<td>123 (11.9)</td>
<td>0.01</td>
</tr>
<tr>
<td>Patients with URI symptoms</td>
<td>20 (20)</td>
<td>169 (16.4)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Patients with history of RAD</td>
<td>25 (25)</td>
<td>196 (18.9)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Age in years, males</td>
<td>5.72 ± 2.12</td>
<td>4.94 ± 1.83</td>
<td>0.0001</td>
</tr>
<tr>
<td>Age in years, females</td>
<td>4.29 ± 1.56</td>
<td>4.29 ± 1.64</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

n.s., not significant; URI, upper respiratory tract infection; RAD, reactive airways disease. Values are numbers (%) or mean ± SD.

### Table 3
Comparison of anesthetic techniques and perioperative complications in obese and nonobese children

<table>
<thead>
<tr>
<th></th>
<th>Obese (n = 100)</th>
<th>Nonobese (n = 1033)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalation induction</td>
<td>99 (99)</td>
<td>1030 (99.7)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>0 (0)</td>
<td>2 (0.19)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Intraoperative vomiting</td>
<td>0 (0)</td>
<td>1 (0.1)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Intraoperative desaturation</td>
<td>2 (2)</td>
<td>2 (0.19)</td>
<td>0.001</td>
</tr>
<tr>
<td>Postoperative desaturation</td>
<td>2 (2)</td>
<td>12 (1.16)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Postoperative emesis</td>
<td>1 (1)</td>
<td>14 (1.36)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hospital admission</td>
<td>2 (2)</td>
<td>2 (0.19)</td>
<td>0.01</td>
</tr>
<tr>
<td>ICU admission</td>
<td>0 (0)</td>
<td>2 (0.19)</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

n.s. = not significant. Values are numbers (%).
percentile cut off point is, however, arbitrary and does not take into account differences in racial or ethnic background, nor changes in population characteristics over time.

We have therefore opted to use the methodology of Cole et al. (2) in defining childhood obesity. Their data were generated from several large international population databases from six different countries to construct different percentile curves of BMI vs age for each country. Using this approach, rather than choosing an arbitrary 95th percentile curve, the cutoff obesity curve is defined as that BMI growth curve which intersects with a projected BMI of 30 kg m$^{-2}$ at age 18. The resulting obesity curves derived from this work appear to be less dependent on country of origin, and using the pooled averages may prove to be a more valid method for international comparisons and for addressing ethnically diverse study populations such as ours.

It is interesting to note that a large number of our obese children were assigned ASA I status at the time of the preanesthetic visit, with the presence of obesity either unrecognized or underappreciated. We speculate that the high prevalence of overweight children has probably shifted our subjective perception of normal body size during preanesthetic visits, where BMI is not usually calculated.

Anesthetic management of the obese, otherwise healthy child can be challenging and has been reported to be associated with a higher incidence of critical incidents during anesthesia (9). It is widely assumed in the anesthesia literature that general anesthesia among obese adults is associated with an overall increased risk of perioperative respiratory and cardiac complications. Pulmonary physiological derangements which accompany adult obesity include decreases in functional residual capacity (FRC), forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1). These findings have been replicated in children (10–11). During general anesthesia, obese adults are more likely to develop rapid oxygen desaturation during periods of apnea (12), and exhibit lower tissue oxygen levels at a given arterial partial pressure of oxygen (PO$_2$). (13) Minor respiratory complications following elective surgery are noted to be more common in obese adults compared with their lean counterparts (7,14).

Obesity is also associated with increased intra-abdominal pressure and decreased lower esophageal sphincter tone. Although it has been widely perceived that obese patients are at increased risk for aspiration during anesthesia induction, this concept has been challenged. Gastric emptying time for clear fluids in otherwise healthy obese adults is no different than in their lean counterparts (15). Warner et al. (16) found no correlation between obesity and pulmonary aspiration in a retrospective review of 215 488 adult general anesthetics. Similarly, in a retrospective data base analysis by Borland et al. (17) of aspiration during 50 880 pediatric anesthetics, only one of the 52 patients who aspirated was obese, and this aspiration was of blood and not stomach contents during dental surgery. Interestingly, in this pediatric study, aspiration was more often associated with intravenous rather than inhalation induction.

Both direct laryngoscopy and mask ventilation have been reported to be more difficult in obese adults, which compound potential difficulties during anesthesia induction (8). Many anesthesiologists utilize intravenous induction, or awake intubation in this population based upon their preoperative airway assessment and personal preference. Young children, parents, and pediatric anesthesiologists, however, often prefer inhalation induction of anesthesia over either intravenous induction or awake intubation. In our study, we noted no airway difficulties in either the obese or nonobese children. We also found no increased risk of vomiting or aspiration related to obesity status. We caution, however, that due to the retrospective nature of the study and the reliance on self-reporting by the anesthesiologist, the incidence of difficulties during mask inhalation induction may have been underreported.

Overall, our study did show a tendency toward more minor complications in the obese group. These complications were predominantly respiratory. Obese patients had a higher rate of oxygen desaturation requiring supplemental oxygen, and unplanned overnight hospital admission.

Caution must be extended in applying our conclusions regarding induction to all obese children. Obstructive sleep apnea may have been underrepresented in our preoperative population, because sleep studies were not performed. Other comorbidities commonly associated with obesity such as diabetes and hypertension were not found in our population. © 2006 The Authors
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This may simply reflect the relatively young age of the children requiring dental restorations, in comparison with the usual older age onset of these associated diseases, and the lack of preoperative screening. Similarly, we only studied patients undergoing dental procedures, which have few systemic physiological trespasses related to the procedure itself. The impact of obesity on the perioperative course of children undergoing more extensive elective surgical procedures remains to be defined.

Although we could not quantify this, our population probably did not include many morbidly obese patients. This has been defined as a BMI > 40 kg m\(^{-2}\) in adults, but has not been similarly delineated in children. The morbidly and super-morbidly (BMI > 50 kg m\(^{-2}\)) obese adults have been demonstrated to have much greater physiological derangements and anesthesia complications. In future studies, it may become important to identify these types of individuals in the pediatric population. Until then, we feel that caution should be exercised in extrapolating our conclusions to children we consider to be morbidly obese.

Overall, we find it reassuring that in the hands of pediatric anesthesiologists, the moderately obese child having minor surgery can undergo general anesthesia safely, with few modifications to accepted inhalation techniques. Because of the overall very low incidence of anesthetic complications, it is possible that studying a larger population may uncover an increased risk associated with obesity.

References


Accepted 28 September 2006