REVIEW ARTICLE

Anesthetizing the obese child

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Introduction

The prevalence of childhood obesity is increasing (1). Obese children are more prone to comorbidities (2) and perioperative complications especially related to airway management and ventilation (3) than normal weight children. Furthermore, obesity influences the pharmacokinetics of anesthetic drugs causing difficulties in the estimation of appropriate drug doses (4). This review focuses on the special anesthetic considerations regarding the perioperative management of obese compared to normal weight children.

Definition, prevalence, and etiology of childhood obesity

Childhood obesity is defined in various ways. In adults, a body mass index (BMI: weight/height²) above 25 and 30 kg/m² defines overweight and obesity. In children, however, median BMI varies with age and sex. Cole has provided an international definition of childhood overweight and obesity with age-specific and gender-specific BMI cutoff points using pooled international data for BMI and linked to adult cutoff points (Figure 1) (5). WHO defines childhood overweight and obesity according to standard deviations (BMI Z-scores) from the mean BMI using other reference data than Cole (6,7). Based on American reference data, the American definition of childhood obesity describes a BMI ≥ 85th percentile as overweight and a BMI ≥ 95th percentile as obesity (8). The estimated degree of childhood obesity depends on the definition used.

Worldwide the prevalence of childhood obesity is rapidly rising. The European prevalence has tripled in the last decades (1) and globally 20 million children under the age of 5 are obese (9). Approximately 20% of European (1) and 32% of American (10) children and adolescents are currently overweight. Using Coles cutoff points (5), the prevalence of overweight and obesity among Danish 3-year-old is 10.4% (11). Among 6–8-year-olds, the prevalence is 21% in girls and 15% in boys (12).

More than 90% of childhood obesity cases are primary, caused by excessive calorie consumption. The remaining cases are secondary to underlying diseases...
Pathophysiology and preanesthetic evaluation

Childhood obesity is associated with numerous comorbidities (Table 1). In most of them, incidences increase with both increasing BMI and duration of obesity, and a weight reduction correlates with a reduction in or normalization of risk factors.

Pediatric obesity correlates with reductions in functional residual capacity (FRC), expiratory reserve volume (ERV), forced expiratory volume in 1 s (FEV₁), and diffusion capacity (DLCO) (22). A resulting high closing volume may cause atelectasis, air trapping, and intrapulmonary right to left shunting with possible hypoxemia. These changes are accentuated in the recumbent position when the abdominal pressure on the diaphragm is highest (23). Childhood obesity may induce bronchial hyperreactivity, and approximately 30% of obese 8–18-year-olds have asthma with increase in both incidence and severity with increasing BMI (14). Furthermore, obese children are more prone to upper airway infections than normal weight children (15).

Obstructive sleep apnea (OSA) is reported in 13–59% of obese children, compared to 1–2% of normal weight children (16). A majority of obese children with OSA will benefit from adenotonsillectomy (24). Snoring is an important indicator of OSA (25). Severe OSA increases the risk of postoperative respiratory depression and airway obstruction (26) and is indicated by apnea episodes, daytime somnolence, learning disabilities, and a family history of OSA (27). Preoperative polysomnography is gold standard to diagnose and estimate the severity of OSA. Children with OSA have a diminished ventilatory response to CO₂ compared to other children (28). This has clinical implications in spontaneously breathing anesthetized children and in the postanesthetic care unit. Use of systemic opioids in children with OSA increases the risk of postoperative respiratory depression (29) and should be followed by monitoring of respiration. A fraction of children with OSA shows an increased sensitivity to both the analgetic and the respiratory depressant effect of opioids (30). If apnea is seen after small dosages of opioids, the child should be treated as having severe OSA, and further opioid dosages should be minimal and followed by close monitoring of respiration (30).

Table 1 Comorbidities associated with childhood obesity

<table>
<thead>
<tr>
<th>Affected organ system</th>
<th>Obesity related comorbidity</th>
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<tbody>
<tr>
<td>Respiratory system</td>
<td>Bronchial hyperreactivity (14)</td>
</tr>
<tr>
<td></td>
<td>Asthma (present in 30%) (14)</td>
</tr>
<tr>
<td></td>
<td>High incidence of upper airway infections (15)</td>
</tr>
<tr>
<td></td>
<td>Obstructive sleep apnea (present in 13–59%) (16)</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Hypertension (present in 20–30%) (2)</td>
</tr>
<tr>
<td></td>
<td>Left ventricular hypertrophy (in adolescents) (17)</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Metabolic syndrome (present in 40–50% of obese adolescents) (18)</td>
</tr>
<tr>
<td></td>
<td>Dyslipidemia (hyperlipidemia and hypercholesterolemia) (19)</td>
</tr>
<tr>
<td></td>
<td>Polycystic Ovarian Syndrome (2)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Gastroesophageal reflux (present in 20% of severely obese children) (20)</td>
</tr>
<tr>
<td></td>
<td>Asymptomatic steatosis hepatitis (present in 80%)</td>
</tr>
<tr>
<td></td>
<td>Could progress into hepatic fibrosis, nonalcoholic acute steatohepatitis or rarely cirrhosis (21)</td>
</tr>
<tr>
<td>Neurological/psychological</td>
<td>Pseudotumor cerebri (2)</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>Slipped femoral epiphysis (2)</td>
</tr>
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</table>
operative management of obese children with OSA includes positioning, use of a nasal airway and in severe cases use of continuous positive airway pressure (CPAP) or bi-level positive airway pressure and prolonged postoperative (overnight) monitoring (26).

Childhood obesity causes increased blood volume and stroke volume with a resulting increase in cardiac output (17). There is a positive correlation between incidence of hypertension and increasing BMI (31); 20–30% of obese children have hypertension (2). Furthermore, left ventricular hypertrophy, hypercholesterolemia, and hyperlipidemia which are also cardiac risk factors are common in obese children (19). Weight loss reduces or normalizes these risk factors (31). Blood pressure should be measured preoperatively and a detailed history of physical ability which is highly consistent with actual physical performance in obese children should be obtained (19) to determine the degree of cardiopulmonary compromise.

Forty to fifty percent of obese adolescents suffer from the metabolic syndrome (18) with a high risk of developing type 2 diabetes mellitus (DM) (32). Thus, in a group of obese children with impaired glucose tolerance, 24% developed type 2 DM within 2 years (33). Type 1 DM is by far the most frequent diabetic form in children (>90%) (34). However, in the US, 45% of pediatric cases of DM are now caused by type 2 DM because of the high prevalence of childhood obesity (35). A preoperative fasting blood glucose level should be obtained, because undiagnosed type 2 DM is frequent (19).

Childhood obesity has been associated with symptoms of gastroesophageal reflux (GER). A positive correlation between the degree of obesity and the risk of GER has been described with symptoms in 20% of severely obese children compared to 2% of normal weight children (20). A 2-h fasting period of clear liquid is sufficient even in obese children with gastroesophageal reflux (36).

The preanesthetic physical examination of obese children should include thorough airway assessment, height, weight and BMI assessment using Coles age-specific and gender-specific curves (Figure 1). Blood pressure, heart rate, fasting blood glucose level, and preoperative pulse oximetry should be obtained. If cardiac disease is suspected, an echocardiography and electrocardiogram should be obtained. Pulmonary function tests should be carried out if respiratory co-morbidity is likely.

Obtaining an intravenous catheter in obese children can be difficult (37). Topical amethocaine causes vasodilation (38) and has been proposed making venous cannulation easier in obese children. An eutectic mixture of local anesthetics (EMLA) causes vasoconstriction (39). No difference in first attempt success rate between the two has been shown in groups of mixed weight children (39).

Pharmacology

Obesity affects the pharmacokinetics of most anesthetics (4). Despite the pharmacokinetic differences between children and adults, extrapolations must be made from studies of obese adults, because of a lack of pharmacokinetic studies of obese children.

Calculation of the optimal drug doses for induction and maintenance of anesthesia are based on the patients total body weight (TBW), ideal body weight (IBW), and lean body weight (LBW).

Figure 2a,b shows gender-specific curves of reference BMI according to age. Using these curves, IBW can be calculated as follows:

\[ IBW = \text{BMI at the 50th percentile for the child's age} \times (\text{height(m)})^2 \]

Figure 3 gives an example of this calculation.

Absolute LBW is increased in obese children compared to normal weight children, because 20–40% of the excessive weight is due to an increase in muscles, bones, and other lean body tissues (40).

Thus, lean body weight can be estimated by the following formula:

\[ LBW = IBW + 0.3 \times (TBW - IBW) \]

Predicting how to dosage different drugs in obese patients can be difficult, e.g. the volume of distribution of some highly lipophilic drugs are increased (e.g. Thiopental) (41) but for others reduced (e.g. Propranolol) (42). Thus, assuming that a highly lipophilic drug should be dosed based on TBW can result in severe overestimation. As a rule of thumb, hydrophilic drugs should be dosed according to IBW.

Finally, drug clearance might be altered in obese individuals whose hepatic and renal clearance may be increased in correlation with LBW (4). However, with an increased volume of drug distribution, elimination half-life might be prolonged (e.g. diazepam) (43).

Monitoring the depth of anesthesia could be helpful in titrating anesthetics in obese children. Owing to age differences in the EEG, methods should be further validated before use in infants (44).

Succinylcholine is the only intravenous anesthetic that has been pharmacokinetically studied in obese children (45). Despite its hydrophilicity, succinylcholine should be dosed according to TBW because of an increased...
pseudocholinesterase activity in this population (45). All other dosage suggestions are based on studies of obese adults and normal weight children (Table 2). Midazolam and clonidine are widely used as preoperative anxiolytics in children. There are no data on optimal dosage of either drug in obese children. We suggest dosage according to IBW to avoid respiratory depression.

Of the inhalational anesthetics, sevoflurane provides more hemodynamic stability (52) and less airway irritability (53) when compared to desflurane and can be used for induction. Desflurane has a lower blood-lipid solubility, (54) provides a faster restoration of protective airway reflexes (54) and perhaps a more rapid recovery profile (53,55) than sevoflurane in obese individuals. Isoflurane has a high blood-lipid solubility (54), which markedly increases recovery time in obese individuals compared to sevoflurane and desflurane (56). In conclusion, sevoflurane may be the inhalational drug of choice for obese children, but studies are performed on obese adults – not children.

Regional anesthesia is common in pediatric anesthesia. The reduced risk of postoperative respiratory depression and airway compromise (57) makes both

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**Table 2 Dosage of intravenous anesthetics in obese children.**

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<thead>
<tr>
<th>Drug</th>
<th>Induction dose based on</th>
<th>Maintenance dose based on</th>
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</thead>
<tbody>
<tr>
<td>Thiopental (4,41)</td>
<td>LBW</td>
<td></td>
</tr>
<tr>
<td>Propofol (46)</td>
<td>LBW</td>
<td>TBW</td>
</tr>
<tr>
<td>Synthetic opioids (Fentanyl, Alfentanil and Sufentanil (4)</td>
<td>TBW</td>
<td>LBW</td>
</tr>
<tr>
<td>Morphine (47)</td>
<td>IBW</td>
<td>IBW</td>
</tr>
<tr>
<td>Remifentanil (48)</td>
<td>LBW</td>
<td>LBW</td>
</tr>
<tr>
<td>Nondepolarizing</td>
<td>IBW</td>
<td>IBW</td>
</tr>
<tr>
<td>Neuromuscular blockers (49)</td>
<td>TBW</td>
<td></td>
</tr>
<tr>
<td>Succinylcholine (45)</td>
<td>TBW</td>
<td></td>
</tr>
<tr>
<td>Sugammadex (50,51)</td>
<td>TBW</td>
<td></td>
</tr>
</tbody>
</table>

TBW, total body weight; LBW, lean body weight; IBW, ideal body weight.

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**Figure 2** Danish BMI for age reference values for a girls and b boys. Source K Nysom, C Mølgaard, B Hutchings and K Fleischer Michaelsen. Body mass index of 0 to 45-y-old Danes: reference values and comparison with published European reference values. (a) (b) Figure 3 Calculation of IBW (IBW, ideal body weight; BMI, body mass index).
peripheral nerve blocks and neuroaxial blockade seemingly attractive for obese children, but there are no studies of this subject. Obese adults have a smaller epidural volume and lumbar cerebrospinal fluid volume when compared to normal weight adults with a consequent risk of increased block height (58). If this is applicable to obese children, dosage of the local analgesic warrants caution.

Airway management

Few studies evaluate airway management and ventilation of obese children – none of these include children younger than 2 years. Two studies have related the degree of obesity to the incidence of perioperative respiratory complications (59,60). No differences were found between normal weight and overweight children, while obese children had a significantly higher risk of airway-related complications compared to the other groups. Obesity, age < 10 years, OSA, and procedures involving the airway were identified as risk factors of perioperative respiratory complications (59).

Owing to higher oxygen consumption and less oxygen reserve, children develop hypoxemia faster than adults (61) and obese children are more prone to intraoperative desaturation than normal weight children (3,59,62). Studies in normal weight children have shown an increase in the nonhypoxic apnea period with age (61). The most efficient method for preoxygenation in normal weight children is 3 min of normal tidal volume breathing (63). Obese children do not have an increased risk of pulmonary aspiration when compared to normal weight children (36,59), and there is no evidence that rapid sequence induction (RSI) should be performed in all obese children.

Children are prone to upper airway collapse during sedation and general anesthesia (64). The risk of difficult mask ventilation is further increased in obese compared to normal weight children (3,59,60). Combining chin lift or jaw thrust with CPAP of 10 cm H2O reduces upper airway collapse in spontaneously breathing, anesthetized normal weight children (65). Furthermore, positive end-expiratory pressure (PEEP) prevents atelectasis of lung tissue and thereby oxygen desaturation (66). Difficult mask ventilation can result in gaseous distension of the stomach, venting will improve FRC and ventilation.

Difficult laryngoscopy in obese compared to normal weight children has been evaluated (3,59,60). The incidences seem to be the same, but results are heterogeneous. When using a laryngeal mask airway (LMA), choosing size according to TBW significantly increases the oropharyngeal leak pressure and gives better ventilating conditions in overweight children (67). Figure 4 shows suggestions for airway management of the obese child.

There are no studies investigating the effects of preoxygenation, positioning, the choice of endotracheal intubation or LMA, use of RSI or choice of ventilation strategy in obese compared to normal weight children. Furthermore, no studies correlate the age of the obese children with the risk of respiratory complications.

Postoperative care

Obese and overweight children have a significantly increased length of stay in the postanesthetic care unit and an increased frequency of unexpected hospital admissions when compared to normal weight children (3,60,62). This may reflect the increased risk of postoperative upper airway obstruction in obese children (3,60). Placing the patient in the semi-recumbent position reduces the risk of atelectasis and improves oxygenation.

There are no studies of postoperative analgesia in obese children. If possible, regional analgesia seems rational to avoid respiratory depression (57). Otherwise, nurse-controlled or patient-controlled analgesia (NCA or PCA) with dosage according to IBW and monitoring of respiration can be used after major surgery.

Conclusion

Anesthesia for obese children is an area of growing interest because of the increasing prevalence of childhood obesity. Many obese children have comorbidities of importance to the anesthetic management. Obesity impacts the pharmacokinetics of most anes-
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The obese child has a significantly increased risk of airway obstruction, intraoperative oxygen desaturation, and difficult mask ventilation. We find no evidence for longer fasting hours, RSI or the use of an endotracheal tube instead of a LMA based on the sole fact that the child is obese.

There is a need of randomized clinical trials to evaluate the anesthetic management of obese children within different age and BMI groups. Finally, pharmacokinetics differs in children and infants compared to adults, but only few pharmacokinetic studies of obese children exist.

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References

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