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13 Anesthetic Management of Morbidly Obese Patients Undergoing Airway Surgery

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Introduction

Obesity has become one of the most important public health problems in the United States and many other countries around the world [1]. In the United States, prevalence of childhood obesity has increased up to threefold over the last three decades [2, 3]. It now affects one in six children and adolescents with the highest prevalence in Black and Mexican-American youth [4]. According to Center for Disease Control and Prevention (CDC) 2011–2014 report, the prevalence of obesity was 17.5% of among 6–11-year-olds and 20.5% of 12–19-year-olds [5]. More than 30% of pediatric patients presenting for surgery in one large pediatric setting were found to be overweight or obese [6].

Along with the increase in weight come a number of potential health issues such as obstructive sleep apnea, metabolic syndrome, and cardiac disease, and it has been shown that comorbidities are more common among obese children. They are at increased risk of adverse events associated with anesthesia and surgical procedures [7]. Obesity is identified as one of the major risk factors of death or permanent neurological injury after tonsillectomy [8].

Morbidly obese children are a special group of patients requiring special attention in the perioperative period especially during airway related surgery. Understanding the anatomical, physiological, metabolic, and pharmacological changes are crucial for the anesthesiologist to tailor the anesthetic technique for the best possible outcomes.

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Defining Obesity in Children

The norms for BMI in children vary with age and sex because of growth and differences in the distribution of fat, muscles, and bone density occurring at puberty. Therefore, specific growth curves showing the percentiles for age- and sex-specific BMI are used to define obesity in children and teenagers from 2 to 18 years of age. In 2000, the National Center for Health Care Statistics and the Centers for Disease Control (CDC) published BMI reference standards for children between the ages of 2 and 20 years (Fig. 13.1a, b). BMI percentiles can also be determined using a simpler alternative "BMI Percentile Calculator for Child and Teen" (aged 2 through 19 years old) available on the CDC website: https://nccd.cdc.

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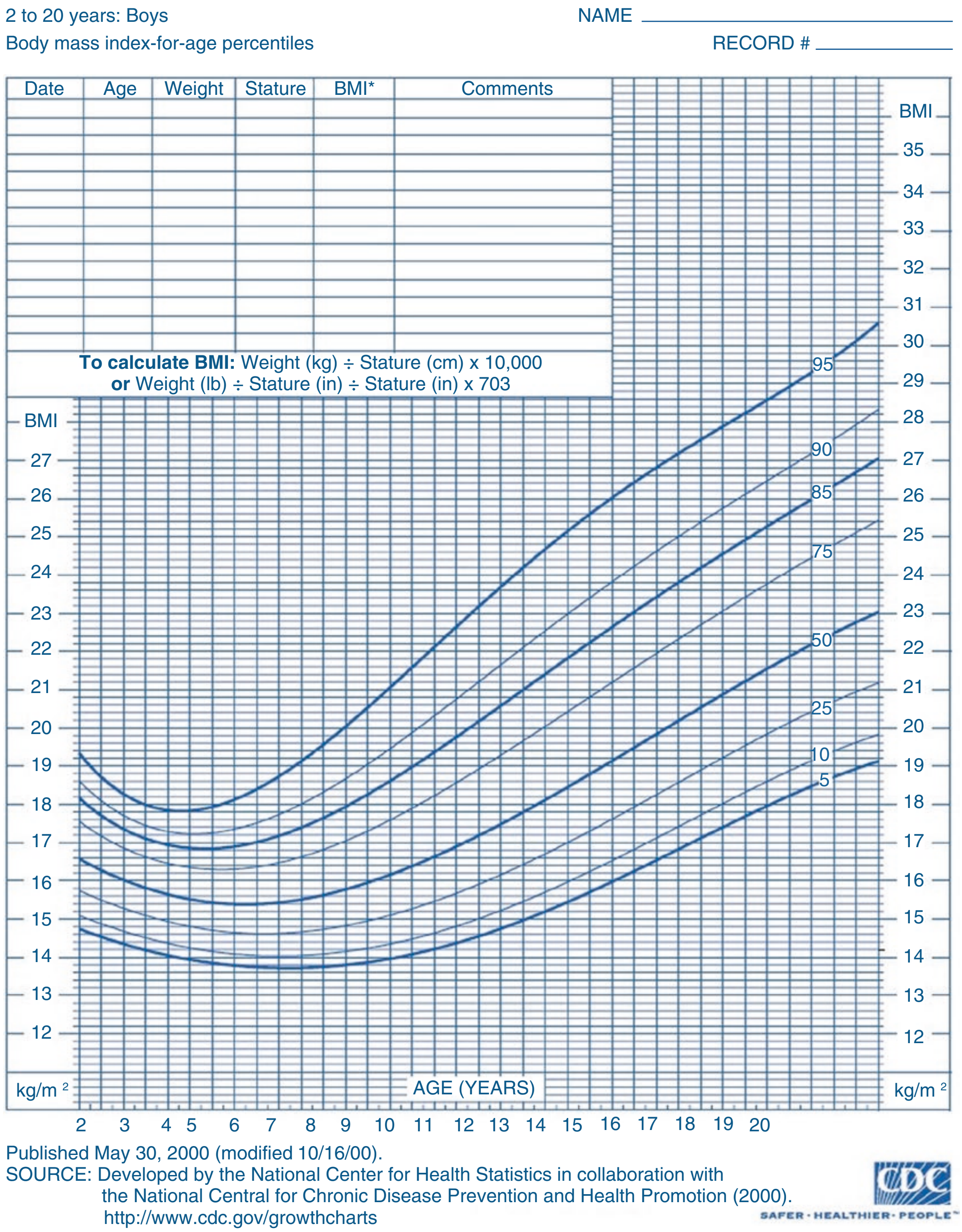

Fig. 13.1 (**a**) Body mass index-for-age percentiles, boys, 2–20 years, CDC growth charts: United States. (**b**) Body mass index-for-age percentiles, girls, 2–20 years, CDC growth charts: United States

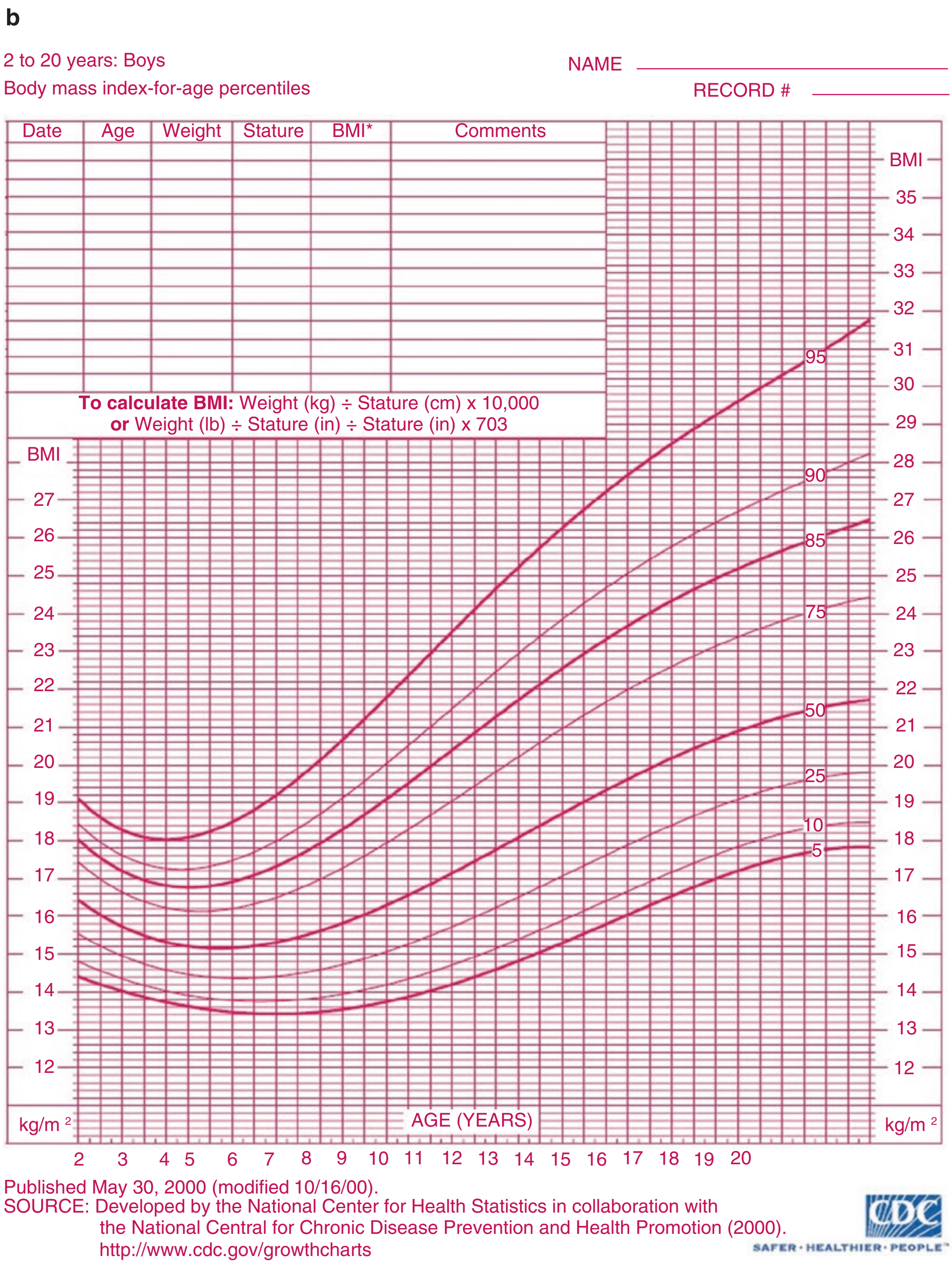

Fig. 13.1 (continued)

Table 13.1 Definition of obesity in children and teenagers

Weight status category	Percentile range
Normal	5th to <85th percentile
Overweight	85th to <95th percentile
Obese	95th to <97th percentile
Morbidly obese	>97th percentile

gov/dnpabmi/Calculator.aspx. This calculator provides BMI and the corresponding BMI-for-age percentile on a CDC BMI-for-age growth chart. The definitions used to categorize weight status for children are shown on Table 13.1. Nafiu et al. proposed a more simplified definition as follows: any preschool age child (aged 2–5 years) with BMI ≥ 20 kgm^2 is classifiable as obese, any school age child (aged 6–12 years) with BMI ≥ 25 kgm^2 is classifiable as obese, and any young adolescent (aged 13–18 years) with BMI ≥ 25 kgm^2 is classifiable as overweight or obese [9]. This group of patients has a significantly greater risk for having perioperative complications [7, 10] and requires special considerations during perioperative period.

Special Risk Considerations for Morbidly Obese Children

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) is a public health problem and is often associated with obesity [11]. The prevalence of OSA in the general pediatric population is estimated to be 1–6%. However, in obese children and adolescents, the evidences suggest that the prevalence and severity of OSA are increased and are reported to be 19–61% [12]. In recent study by Mathew et al., 24% of morbidly obese (>150% IBW) children and young adults (3–20 years old) had OSA using an AHI >5/h. Moreover, SaO_2 was <90% for >3% of the total sleep time in 20% of these children [13].

There are four common clinical phenotypes that associate with OSAS in children: (1) obesity, (2) lymphoid hypertrophy, (3) craniofacial, and (4) neuromuscular. The prevalence of OSAS in obese children seems to exceed that of any other phenotype. A population-based study involving children between 2 and 18 years of age found that obesity was the most significant risk factor for OSAS [14]. However, it is not uncommon that more than one cause may have contributed to their OSAS. It has been shown that about 45% of obese children with OSAS have evidence of adenotonsillar hypertrophy [11].

Both anatomic and functional factors contribute to pathophysiology of OSAS in obese children. Anatomical obstruction is caused by adenotonsillar hypertrophy and parapharyngeal fat pads. The latter have been shown to be significantly larger in obese subjects with OSA, when compared to BMI-matched subjects without OSA [13]. Functional mechanisms can be explained by alterations in neuromotor tone and tissue properties that lead to increased airway collapsibility and increased resistance. Obese children with OSAS having large tonsils and adenoids do not obstruct while awake because of high motor tone, and adenotonsillectomy in these children does not cure OSAS in a large number of patients [11].

The presence of a diagnosis of OSA in morbidly obese children carries implications for the anesthetic technique and disposition planning. In 2014, the American Society of Anesthesiologists Task Force on Perioperative Management of patients with OSA published an updated report of Practice Guidelines for the Perioperative Management of Patients with OSA which includes the clinical criteria to identify and assess OSA in children (Table 13.2) [15]. The recommendation is that if any characteristics noted during the preoperative evaluation suggest that the patient has OSA, the anesthesiologist and surgeon should jointly decide whether to (1) manage the patient perioperatively based on clinical criteria alone or (2) obtain sleep studies, conduct a more extensive airway examination, and initiate indicated OSA treatment in advance of surgery. If the decision is to proceed without a sleep study, such patients should be treated as though they have moderate sleep apnea unless one or more of the signs or symptoms above is severely abnormal (e.g., markedly increased BMI, respiratory pauses

Table 13.2 Identification and assessment of OSA in children (modified from practice guidelines for the perioperative management of patients with obstructive sleep apnea: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea) [15]

A. Clinical Signs and Symptoms Suggesting the Possibility of OSA

1. Predisposing physical characteristics
   - BMI: 95th percentile for age and sex
   - Craniofacial abnormalities affecting the airway
   - Anatomical nasal obstruction
   - Tonsils nearly touching or touching in the midline
2. History of apparent airway obstruction during sleep: two or more of the following are present
   - Intermittent vocalization during sleep
   - Parental report of restless sleep, difficulty breathing, or struggling respiratory efforts during sleep
   - Night terrors
   - Child sleeps in unusual positions
   - New onset enuresis
3. Somnolence (one or more of the following is present)
   - Parent or teacher comments that child appears sleepy during the day, is easily distracted, is overly aggressive, is irritable, or has difficulty concentrating
   - Child often difficult to arouse at usual awakening time

If a patient has signs or symptoms in two or more of the above categories, there is a significant probability that he or she has OSA. The severity of OSA may be determined by sleep study (see below). If a sleep study is not available, such patients should be treated as though they have moderate sleep apnea unless one or more of the signs or symptoms above is severely abnormal (e.g., markedly increased BMI, respiratory pauses which are frightening to the observer, patient regularly falls asleep within minutes after being left unstimulated without another explanation) in which case they should be treated as though they have severe sleep apnea.

B. Sleep Study

If a sleep study has been done, the results should be used to determine the perioperative anesthetic management of a patient. However, because sleep laboratories differ in their criteria for detecting episodes of apnea and hypopnea, the sleep laboratory's assessment (none, mild, moderate, or severe) should take precedence over the actual AHI. If the overall severity is not indicated, it may be determined by using the table below:

Severity of OSA	Pediatric AHI
None	0
Mild OSA	1–5
Moderate OSA	6–10
Severe OSA	>10

AHI apnea–hypopnea index: the number of episodes of sleep-disordered breathing per hour

which are frightening to the observer, patient regularly falls asleep within minutes after being left unstimulated without another explanation) in which case they should be treated as though they have severe sleep apnea [15]. However, the Childhood Adenotonsillectomy (CHAT) Study Randomized Clinical Trial demonstrated that OSA severity could not be accurately predicted by traditional clinical parameters alone [16]. The American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) advocates for preoperative PSG in children with obesity prior to undergoing tonsillectomy to help plan perioperative management, provides a baseline for postoperative polysomnography (PSG), and defines severity of sleep disturbance [17].

Difficult Airway and Ventilation

In obese children, the risk for desaturation during induction of anesthesia, emergence, and in the postoperative care unit is greater compared with normal-weight children because of the following physiologic and anatomical changes associated with obesity (Fig. 13.2) [18].

1. *Higher incidence of upper airway obstruction and difficult airway*
   Mask ventilation and intubation can be more difficult in obese children. Jaw thrust, two-hand mask ventilation, or the use of oropharyngeal or nasopharyngeal airways is more often necessary to achieve sufficient mask ventilation. The causes of obesity-related difficult airway can be explained by the following:
   - MRI in obese adults shows that there is increased deposition of adipose tissue into the uvula, tonsils, tonsillar pillars, tongue, aryepiglottic folds, and lateral pharyngeal walls resulting in decreased pharyngeal space volumes. Obese children with OSA have higher tonsil volume than normal-weight children which may result in the higher incidence of upper airway obstruction after induction of anesthesia, as all commonly used anesthetic drugs have been demonstrated to cause pharyngeal collapse.

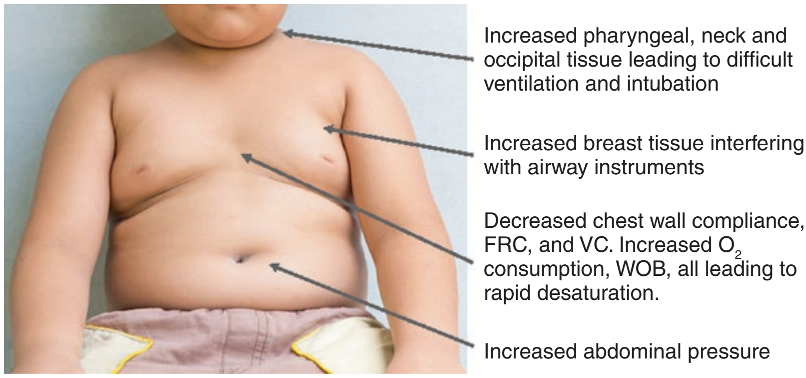

Fig. 13.2 Physiologic and anatomical changes associated with obesity resulting in difficult airway and ventilation

- The pharynx is collapsible because its anterior and lateral walls lack bony support. Its patency is dynamic and determined by the transmural pressure across its walls and the compliance of the walls. In obese adults, extraluminal pressure is increased by superficially located fat that may compress the upper airway externally.
- The short, thick neck may limit neck extension during laryngoscopy, and the larger tongue may make intubation difficult.

2. *Reduced Tolerance to Hypoventilation/Apnea*
   During apnea, morbidly obese children have a shorter time to desaturation which greatly increases the risk of hypoxic injury if airway difficulties are encountered. Rapid desaturation can be explained by the following:
   - They have altered respiratory physiology: decreased respiratory compliance, vital capacity, and functional residual capacity. V/Q mismatching increases more after induction of anesthesia due to atelectasis in supine position leading to hypoxia. Positive end-expiratory pressure (PEEP) should be applied during induction and maintenance of anesthesia to increase the functional residual capacity (FRC) and prevents atelectasis.
   - Increased work of breathing and oxygen consumption from increase fat and muscle tissues.

Comorbidities

Childhood obesity is associated with multisystem pathophysiologic changes leading to numerous comorbidities (Table 13.3) [18, 19]. Interestingly, both obesity and untreated OSAS are independently associated with similar cardiovascular, pulmonary, and metabolic morbidities. However, the magnitude of derangement when obesity and OSA coexist is unclear but likely to be at least additive. Most of the abnormalities are mediated via the sympathetic nervous system, oxidative stress, and inflammation. The consequences are mainly on the cardiovascular system such as systemic hypertension, ventricular hypertrophy, or even pulmonary hypertension leading to right heart failure. In most of comorbidities, incidences increase with increasing BMI and duration of obesity [18].

Medication Dosing

Drug dosing in a morbidly obese patient continues to be problematic because of a relative lack of evidence and understanding regarding how to safely and effectively dose medications for them. Pharmacokinetic studies of anesthesia-related drugs in obese adults are limited, and there are even less data about children and adolescents; thus extrapolations have to be made from studies of obese adults. It was found that obese children had a greater odd of being dosed with medications outside their recommended ranges. These findings suggest that they are potentially at greater risk of medication ineffectiveness (underdosing) or adverse events (overdosing) [20]. For certain medications, the target effect can be measured, and their dosing can be based on that endpoint such as peripheral nerve stimulation for

Table 13.3 Comorbidities and pathophysiologic changes in obese children [18, 19]

System	Comorbidities	Pathophysiologic changes
Respiratory	OSAS Chronic Hypoxia Asthma Bronchial hyperactivity Atelectasis	Decrease in: • Lung volume: FRC, VC, inspiratory capacity • Diffusion capacity • FEV_1 • Chest wall and lung compliance Increase in: • Work of breathing • Lower airway obstruction • Closing Capacity • Exercise-induced asthma in 30% of overweight and obese children • OSA in about 17% of the obese children >150 percentile with chronic nocturnal hypoxemia leads to progressively pulmonary hypertension
Cardiovascular	Hypertension Left ventricular hypertrophy Cor pulmonale	Increase in: • Vascularization of the adipose tissue: increase in cardiac output and blood volume stiffness and wall thickness of the carotid artery as early signs of arteriosclerotic process in school children • Early development of arterial hypertension, approximately a threefold higher risk than nonobese children • Activity of sympathetic nervous system: higher resting heart rate and blood pressure • Left-ventricular mass and hypertrophy • Left-ventricular dysfunction
Endocrine	Diabetes Glucose intolerance Dyslipidemia	Metabolic syndrome and resistance to insulin in 50% of severely obese adolescents
Gastrointestinal	Gastroesophageal reflux? Fatty liver disease	Ambiguous data about reflux: higher incidence of reflux in obese children, and no difference between normal-weight and obese children No difference in residual gastric volume after 6 h fasting and 2 h without liquid between obese and normal-weight children Fatty liver disease: progress from hepatic fatty degeneration to fibrosis (histologically)
Neurological/ psychological	Pseudotumor cerebri Low self-esteem Poor school performance	Hypersomnolence, but more often they display hyperactivity or aggressiveness, poor attention, and poorer performance in school

muscle relaxant, BIS for sedatives. However, there is no specific and reliable monitoring for analgesics especially opioids; therefore careful titrating of small incremental dose to respiratory rate and CO2 is advised.

Calculation of the optimal drug doses for induction and maintenance of anesthesia are based on total body weight (TBW), ideal body weight (IBW), or lean body weight (LBW) [19] (Table 13.4).

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

BMI at the 50th percentile can be identified by using CDC age- and gender-specific curves of reference BMI.

$$\text{LBW} = \text{IBW} + 0.3 \times (\text{TBW} - \text{IBW})$$

LBW is increased in obese children because 20–40% of the excessive weight is due to an increase in muscles, bones, and other lean body tissues [21]. Most of the metabolic processes involved in pharmacokinetics and pharmacodynamics take place in the lean body mass. Lean body mass changes with sex, height, and TBW. Important pharmacokinetic variables such

Table 13.4 Dosage of common intravenous anesthetics in obese children [19, 22]

Drug	Initial dose	Maintenance dose
Sedatives		
Propofol	LBW	TBW
Thiopental	LBW	
Midazolam	?	
Dexmedetomidine	LBW	LBW
Opioids		
Morphine	IBW	IBW
Fentanyl and sufentanil	TBW	LBW
Remifentanil	LBW	LBW
Muscle relaxants and reversal agents		
Succinylcholine	TBW	
Non-depolarizing muscle relaxant	IBW	IBW
Sugammadex	TBW	
Neostigmine	TBW	

as volumes of distribution and clearance can be related to LBM. Cardiac output, an important factor in early distribution of drugs, correlates with BMI but in a nonlinear fashion [22].

Most of the sedatives and anesthetics are lipophilic molecules. Volume of distribution of these drugs is higher as the fat mass increases in obese patients. Loading dose requirement is theoretically affected directly by volume of distribution. Therefore, for most lipophilic drugs, loading dose should be calculated based on TBW. Maintenance dose of drug is generally based on its clearance. However, this pharmacokinetic data is usually not available for obese children. Moreover, alteration in pharmacodynamics, increased sensitivity, of sedatives and anesthetics in obese patient is unpredictable and needs to be considered. Thus, the maintenance dose based solely on total body weight and clearance alone would likely result in overdose. It is recommended that lipophilic drugs should be re-dosed based upon clinical studies based evidence. However, if no data is available, LBW-based maintenance dose can be used but with caution [23].

For hydrophilic drugs, the volume of distribution does not increase proportionately to the increased BMI. Thus loading doses of these drugs should be estimated based upon the lean body mass rather than actual weight. Estimates for maintenance doses of these drugs are more complicated. Most antibiotics and neuromuscular blocking agents are classified as hydrophilic drugs. Penetration of antibiotics into tissue in obese may be lower resulting in lower minimum inhibitory concentrations (MICs). Therefore, higher doses for antibiotics may be needed. On the contrary, obese are more predisposed to residual effects of neuromuscular blockers and thus may require lower target site concentrations [23].

A recent study by Olutoye et al. has shown that the ED_{95} of propofol for loss of consciousness is significantly lower in obese children than in their normal-weight peers and recommended a propofol induction dose of 2.0 mg/kg based on the actual body weight in obese children with BMI > 95th percentile, 3.2 mg/kg for children with BMI < 85th percentile, and 2.5–3.2 mg/kg for the rest [24]. It has been shown that the induction dose of propofol should be calculated based on LBW [25]. However, in morbidly obese children and adolescents has shown that TBW was the main determining factor of propofol clearance. As a result, its maintenance dose should be based on TBW [26].

Non-depolarizing muscle relaxants should be based on LBW. It is recommended that succinylcholine and neostigmine be dosed to TBW. The safest reversal dose of sugammadex for rocuronium and vecuronium is calculated on TBW as well. Dosage of remifentanil and fentanyl should be calculated on LBM. Pharmacokinetic models for sufentanil incorporate TBW. With an unchanged systemic clearance but a marked increased distribution volume, lower midazolam concentrations and sedative effects may be expected in obese compared to normal-weight adolescents. The findings imply that a higher initial dose of midazolam may be needed for this population group [22, 27].

Opioid Sensitivity

In animal model, chronic hypoxia due to repeated episodes of desaturation from severe OSAS results in upregulated increase in the density of mu opioid receptors in the respiratory-related areas of the brainstem. Therefore, both respiratory depressant effect and analgesic effect occur at lower blood concentrations of opioids than in patients or animal models who have not experienced repeated episodes of desaturation. In children with severe OSA, the severity of the nocturnal oxygen desaturation (nSAT) correlates with the sensitivity to exogenously administered opioids. The morphine dose required to achieve a uniform analgesic endpoint in children with OSA who exhibited a low preoperative nSAT <85% was less than in those whose preoperative nSAT >85% (Fig. 13.3) [28–30]. Children with OSAS who underwent tonsillectomy required lower doses of opioids (1/3 to ½ of standard dose) to achieve the same level of analgesia compared with children undergoing the same procedure but for the indication of recurrent tonsillitis [30, 31]. An unforeseen risk of perioperative opioid use in children with severe OSA is that age-appropriate doses of opioids may produce exaggerated respiratory depression. If apnea is seen after small dosages of opioids, the child should be treated as having severe OSA, and further opioid dosages should be completely avoided or minimal and followed by close monitoring of respiration. Children with severe OSAS who exhibit nocturnal hypoxemia require OSA-appropriate opioid regimens.

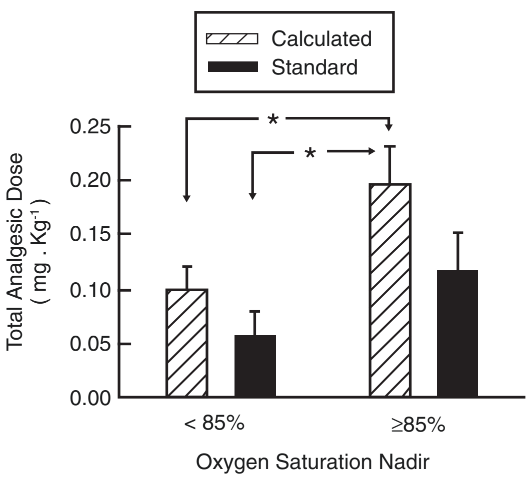

Fig. 13.3 Mean total analgesic morphine dose in children with obstructive sleep apnea after adenotonsillectomy. Children who received the calculated regimen (50% of [0.0007 · age (months)] + [0.0021 · saturation nadir (%)] – 0.1138 mg/kg/dose.) for analgesia are designated by the hatched bar, and those who received the standard pediatric morphine regimen (0.05 mg/kg/dose) are designated by the filled bar

The key strategy in providing safe and effective postoperative pain relief in morbidly obese children is avoiding potent opioids where possible by using multimodal analgesia. These following aspects should be considered [22].

1. Initiate these methods to reduce the need for opioid use intraoperatively, which then will facilitate the reduction of postoperative opioid use.
2. Using core analgesics in line with the steps in the WHO pain ladder.
   - Step 1: Non-opioids – acetaminophen + NSAIDS
   - Step 2: Weak opioids – tramadol
   - Step 3: Strong opioids – narcotics, titrated to effect while monitoring respiratory rate and end-tidal CO_2 levels
3. Incorporation of opioid-sparing adjuvant agents: such as dexamethasone, dexmedetomidine, ketamine, and lidocaine.
4. Use of local or regional anesthesia whenever feasible.

Opioid-free anesthesia and postoperative analgesia for airway surgery can be easily achieved by combining above non-opioid drugs and adjuvants as each of these drugs has been shown to reduce the opioid requirement peri- and postoperatively. Dexmedetomidine has not only analgesic effects but also sedative and autonomic blocking effects. Its autonomic blocking effects are especially beneficial during opioid-free anesthesia. Unlike most of anesthetic agents that reduce pharyngeal tone, diminish the ventilatory response to carbon dioxide, and impair patients' ability to rescue themselves from obstructive apnea during sleep, dexmedetomidine does not produce significant respiratory depression and maintains airway tone with an easily arousable sedation state. These effects may be particularly useful in children with severe OSAS [14, 32]. Perioperative dexmedetomidine administration as an adjuvant leads to significant opioid sparing in morbidly obese adolescent and adult patients undergoing bariatric surgery with overall better pain control and without any reported major adverse events [33, 34].

Risk of Aspiration

Cook-Sather et al. studied gastric fluid characteristics in pediatric patients undergoing day surgery and found that obese children had similar gastric fluid volume (per IBW) and pH when compared to nonobese children [35]. However, they may be at slightly increased risk of pulmonary aspiration due to increased intra-abdominal pressure from a greatly thickened abdominal wall. The indication for rapid sequence induction should always be questioned in the fasting obese child because the risk of hypoxia during rapid sequence induction is higher than the potential risk of pulmonary aspiration. It cannot be generally recommended to apply a rapid sequence induction in elective cases in obese children.

Ambulatory Surgery

For morbidly obese children, the indication for surgery and the presence of other comorbidities are used to determine if surgery can proceed at the ambulatory surgical center. Children with no significant comorbidities presenting for peripheral surgery may be accepted on a case-by-case basis. Morbidly obese children undergoing airway surgery are not acceptable candidates for ambulatory surgery because almost all of them have severe OSAS and other comorbidities. Despite removal of the hypertrophied tonsils and adenoids, children with severe OSAS continue to demonstrate obstructive apnea and desaturation during sleep on the first night after adenotonsillectomy. This underscores the need to admit these children to a hospital for continuous overnight monitoring postoperatively. Because the onset of respiratory complications in children with severe OSAS may be delayed, practice guidelines from the AAO-NHS, the AAP, and the ASA all recommend that discharge criteria from a monitored setting should include observation with saturation monitoring during sleep [15, 36].

One major problem in using this guideline is that percentile does not directly measure body fat. Some very athletic adolescents can have a high BMI-for-age due to extra muscle mass, but not necessarily excess body fat [36].

IV Access

Securing of peripheral venous lines before induction is recommended in morbidly obese children. Dealing with difficult airway while trying to place intravenous lines in this group of patients may be unsafe. This can be achieved by combination of topical anesthetic cream (EMLA – Lidocaine/Prilocaine) or commercial local anesthetic patch (Synera – Lidocaine/Tetracaine) and 50% Nitrous oxide with minimal patient's movement, even in small children (Author's experience). After a contact time of 35 min, the Synera patch led to superior analgesia during venous puncture in children than the EMLA patch. With regard to visibility of the veins and success rate of the punctures, differences between the two patches were not observed [37].

Frequently, peripheral intravenous line placements can be very difficult or impossible, causing severe stress and time-consuming in morbidly obese children. They were more likely to have failed first attempt than the lean controls, and the most likely site for success after failed attempt on the back of the hand is the volar surface of the wrist [38]. Therefore local anesthetic cream application to reduce pain during venous puncture should be applied to both at the back of the hand and on the volar surface of the wrist. The anesthesiologist and the surgeon must balance the value of persisting vs. proceeding with securing the airway first. In children presenting with history of difficult venous access, ultrasound-guided peripheral venous access leads to faster peripheral IV access, lower median number of punctures, and higher success rate at first cannulation [39]. Central venous line is rarely indicated during airway surgery.

Common Airway Surgery in Morbidly Obese Children

Adenotonsillectomy

Tonsillectomy with or without adenoidectomy represents about 15% of all surgical procedures performed on children annually in the United States, and approximately one-third of those children are overweight or obese [40]. Even though studies have shown that obese children with OSA benefit less from adenotonsillectomy compared to normal-weight children [11] suggesting that obesity itself plays an important role in the pathogenesis of OSA in obese children, adenotonsillectomy is still considered to be the first-line treatment of OSA for obese children with adenotonsillar hypertrophy [12]. In a study at the Mayo clinic in Rochester, morbidly obesity (BMI > 98th percentile) in children undergoing tonsillectomy has been shown to independently increase the risk of perioperative respiratory complications even after adjusting for the presence of severe systemic disorders or syndromes and preoperative respiratory disorders. It was also associated with an increased rate of unplanned hospital admission [41]. A more recent study confirmed that obesity is associated with a 67% increase in major and minor respiratory complications when compared to nonobese children [42].

The anesthetic goals for adenotonsillectomy in morbidly obese children are (1) to provide a smooth, atraumatic induction without airway obstruction or desaturation, (2) to achieve a secured airway throughout the procedure, (3) to establish IV access for volume expansion and medications as indicated, (4) to provide the surgeon with optimal operating conditions, (5) to provide rapid emergence so that the child is awake and able to protect the recently instrumented airway, and (6) to provide adequate perioperative analgesia without airway obstruction and respiratory depression [28].

Pre-anesthetic Evaluation and Preparation

The preoperative assessment should focus on airway issues (OSAS, history of airway difficulty with previous anesthetics), cardiopulmonary issues (especially pulmonary hypertension), and other common comorbidities. All morbidly obese children presenting for adenotonsillectomy should be presumed to have OSAS.

The family interview should include focused questions related to snoring, apneic episodes, frequent arousals during sleep, and daytime somnolence. ASA has published practice guidelines for the perioperative management of patients with obstructive sleep apnea which includes clinical signs and symptoms as well as sleep study criteria to identify and assess OSA in children (Table 13.2) [15].

In North America, the indication for adenotonsillectomy in 77% of children is obstructive breathing [109, 112, 113]. The reality is that less than 10% are evaluated with a sleep test prior to surgery. The challenge is to evaluate the severity of SDB based on clinical criteria alone.

The ASA has created a risk assessment scoring system for patients with sleep apnea (Table 13.5) [15]. There are three areas scored: the severity of sleep apnea, the invasiveness of surgery, and the requirement for postop opioids. Each area is scored on a scale of 0–3. Total point score is combination of severity of OSA points and the greater of the score for either type of surgery and anesthesia points or opioid requirement points (6 is at the highest possible score). Patients with score of 4 may be at increased perioperative risk from OSA, and patients with a score of 5 or 6 may be at significantly increased perioperative risk from OSA. Per this scoring system, morbidly obese children with severe OSAS undergoing adenotonsillectomy would be scored with the highest risk of 6 points.

Preoperative polysomnography (PSG) remains the gold standard to diagnose and estimate the severity of OSA. The AAO-HNS advocates for PSG before tonsillectomy in high-risk children with sleep-disordered breathing if they exhibit certain complex medical conditions including obesity, Down syndrome, craniofacial abnormalities, and neuromuscular disorders [17]. Review of sleep studies is crucial for making a safe anesthetic plan. AHI ≥15 and O_2 saturation nadir <80% on PSG have been shown to be inde-

Table 13.5 Scoring system for perioperative risk from OSA [15]

A. Severity of sleep apnea based on sleep study (or clinical indicators if sleep study is not available)	
Severity of OSA points	Points
None	0
Mild	1
Moderate	2
Severe	3
B. Invasiveness of surgery and anesthesia	
Type of surgery and anesthesia points	
Superficial surgery under local or peripheral nerve block anesthesia without sedation	0
Superficial surgery with moderate sedation or general anesthesia	1
Peripheral surgery with spinal or epidural anesthesia (with no more than moderate sedation)	1
Peripheral surgery with general anesthesia	2
Airway surgery with moderate sedation	2
Major surgery, general anesthesia	3
Airway surgery, general anesthesia	3
C. Requirement for postoperative opioids	
Opioid requirement points	
None	0
Low-dose oral opioids	1
High-dose oral opioids, parenteral, or neuraxial opioids	3
D. Estimation of perioperative risk	
Total point score = the score for A + the greater of the score for either B or C	0–6

Table 13.6 Role of PSG in assessing obese children before tonsillectomy for SDB

Role of PSG	Rationale
Avoid unnecessary or ineffective surgery in children with primarily nonobstructive events	Identify primarily nonobstructive events or central apnea that may not have been suspected prior to the study and may not benefit from surgery
Confirm the presence of obstructive events that would benefit from surgery	The increased morbidity of surgery in obese children requires diagnostic certainty before proceeding
Define the severity of SDB to assist in preoperative planning	Obese children with severely abnormal SDB require preoperative cardiac assessment, pulmonary consultation, anesthesia evaluation, or postoperative inpatient monitoring in an intensive care setting
Provide a baseline PSG for comparison after surgery	Persistent SDB or OSA despite surgery is more common in obese patients than in otherwise healthy children
Document the baseline severity of SDB	High-risk patients are more prone to complications of surgery or anesthesia

pendent predictors of postoperative O_2 saturation <90% and length of stay >24 h following adenotonsillectomy in children with severe OSA [43]. A recent study found that AHI $\geq$ 40 is a strong predictor of postoperative respiratory complications in children undergoing tonsillectomy for OSA [44]. Role of PSG in assessing high-risk populations before tonsillectomy for SDB is summarized in Table 13.6 [17].

Nocturnal oximetry may be the preferred first test to help identify severe OSA in younger children as they may not be cooperative with a PSG study. However, some of these children exhibit a high central apnea index and a low obstructive AHI without desaturation events so that a negative test with nocturnal oximetry does not exclude severe OSA.

Children with cardiac involvement from OSA and obesity are at increased risk of perioperative cardiopulmonary complications. Echocardiography is recommended for cardiac evaluation for any child with signs of right ventricular dysfunction, systemic hypertension, or multiple episodes of desaturation below 70% on PSG. Electrocardiogram and chest radiograph are not sensitive evaluation tools. Routine blood gas analysis is not necessary, but a basic metabolic panel can identify a patient with compensatory metabolic alkalosis in response to chronic hypercarbia, and a hemoglobin level may identify the patient with severe chronic hypoxemia [45]. Table 13.7 summaries recommended preoperative laboratory investigation for morbidly obese children undergoing adenotonsillectomy.

Using of a continuous positive airway pressure (CPAP) device prior to surgery has been shown to be beneficial in adult patients with severe OSA [46]. Effective CPAP/BiPAP therapy may improve pulmonary hypertension [45], and according to ASA guideline, its initiation should be considered to reduce perioperative risk from

Table 13.7 Preoperative laboratory investigation for morbidly obese children undergoing adenotonsillectomy

Laboratory Investigation	Rationale
Blood testing	Hemoglobin levels: baseline level before surgery and polycythemia in the patient with severe chronic hypoxemia Basic metabolic panel: metabolic alkalosis in response to chronic hypercarbia Fasting glucose levels: higher incidence of diabetes
ECG	An ECG should be obtained in morbidly obese children with severe OSAS to look for evidence of pulmonary hypertension and right heart failure
Echocardiography	There are no publications showing a positive predictive value of routinely performed preoperative echocardiography in morbidly obese children. However, for patients with positive evidence of pulmonary hypertension and/or right heart failure on ECG or with history of a poor functional capacity, echocardiogram should be performed
Polysomnography	Sleep study is the gold standard to diagnose and estimate the severity of OSA
Spirometry	There is no evidence for routinely performed spirometry in obese children The use of spirometry in patients with OSA or other respiratory findings seems to be supported by current evidence

OSA, particularly if OSA is severe [15]. One point may be subtracted from total OSA risk score if a patient has been on CPAP before surgery and will be using his or her appliance consistently during the postoperative period. However, there are no reports on its impact to support this measure in children [47].

Premedication

The goal is to calm the child while avoiding the sedative and respiratory depressant effects of anxiolytics whenever possible. Preoperative anxiolysis and sedation can increase the risk of excessive postoperative sedation as its residual effects may persist, especially after relatively short surgical procedure like tonsillectomy, and may potentially exacerbate postoperative respiratory complications as well as prolong recovery room stay. Distraction techniques and parental presence during induction are preferable than premedication with anxiolytics in children with significant OSA. Transient oxygen desaturation has been reported in 1.5% of children with OSA who received 0.5 mg/kg oral midazolam [48]; thus after administration of premedication, all children with severe OSA with symptoms of sleep-disordered breathing should be closely monitored with continuous pulse oximetry [49, 50], and premedication with short-acting drugs and/or those that can be antagonized such as midazolam is advised. However, midazolam PO is seldom given to obese children since the maximum dose of 20 mg would be ineffective in a very large child.

Monitoring

Standard monitoring is usually adequate for adenotonsillectomy surgery in obese children. Larger blood pressure cuffs are needed for accurate measurement. In patients of significant associated cardiac morbidities, an arterial line for invasive blood pressure monitoring and blood gas analysis should be considered. Monitoring of anesthetic depth using bispectral index (BIS) devices may be helpful to guide the correct dosage of hypnotic drugs [18].

Induction/Airway Management

Morbidly obese children with severe OSA can quickly obstruct and become desaturated during induction. Anesthesia clinicians should be prepared for management of the potentially difficult mask ventilation or endotracheal intubation in these patients, with difficult airway equipment and assistance readily available. They should be pre-oxygenated in reverse Trendelenburg position prior to induction of anesthesia. Proper positioning can significantly improve respiratory mechanics and oxygenation by decreasing the high intra-abdominal pressure and may improve the success in airway manipulation. "Ramping" is a well-described position for adult obese patients being readied for airway manipulation. It is essentially positioning to obtain a horizontal plane between the external auditory meatus and sternal notch. The goal is to provide upper torso and head/neck elevation coupled with neck extension, so the patient's face is parallel to the ceiling. This "Ramped" position improves access to the airway in a variety of ways and offers several advantages including (1) improved line of sight and laryngoscopy view, (2) augmented respiratory effort and improved pulmonary mechanics, (3) downward gravitational displacement of torso/breasts, (4)"open" submental space between mandible/chin and sternum, (5) ease mouth opening (more space for mandibular hinging), (6) ease cricoid-laryngeal cartilage manipulation, (7) provide improved access for invasive/surgical options, (8) more room to manipulate conventional/advanced laryngoscopic devices, and (9) improved mask ventilation [51].

Application of continuous positive airway pressure of 5 cm H_2O by using tight-fitting mask during preoxygenation has been shown to prevent desaturation episodes in a rapid sequence induction in adult obese patients [52]. Preoxygenation with pressure support of 10 cm H_2O and PEEP of 10 cm H_2O for 5 min can add up to a 140 mm Hg to the PaO_2, improving the apnea time by another minute [53]. However this maneuver can be uncomfortable and may be impractical in younger children.

During induction of anesthesia, early pharyngeal airway obstruction may require a jaw thrust maneuver, insertion of an oral or nasopharyngeal airway, and the application of continuous positive airway pressure (CPAP). When an inhalational induction is performed, care must be used to avoid placing an airway, while patients still react to stimulation, or laryngospasm may occur. Persistent respiratory efforts against an obstructed airway from laryngospasm or pharyngeal airway obstruction can result in negative pressure pulmonary edema [14]. The studies indicate that children with high BMI and sleep-disordered breathing undergoing both ENT and non-ENT surgery are at increased risk for perioperative laryngospasm. Mechanisms underlying these increased risks are unclear. One clinical explanation could be light anesthesia since difficult mask ventilation is more commonly reported in children with high BMI and SDB. Other explanations include increased airway sensitivity and possible subclinical airway inflammation [10]. In morbidly obese children with severe OSA, it is prudent to consider securing IV access before induction of anesthesia to expedite administration of muscle relaxants, or IV agents should pharyngeal obstruction, or laryngospasm occur during induction to facilitate rapid instrumentation of the airway. Propofol-associated loss in airway caliber can be reversed with the application of CPAP. CPAP acts as a pneumatic splint to increase the caliber of the pharyngeal airway. Of equal importance, CPAP increases longitudinal tension on the pharyngeal airway, thereby decreasing the collapsibility of the upper airway, and increases lung volumes. Small increments in CPAP between 5 and 10 cm H_2O increase the dimension of the pharyngeal airway dramatically [28].

The use of the laryngeal mask airway (LMA) for adenotonsillectomy was described in 1990, but it was not until the widespread availability of a model with a flexible spiral, metallic reinforced shaft made it practical for use in adenotonsillectomy [28]. It is used in some centers for tonsillectomy because it is less stimulating to the airway and usually results in a smoother extubation with less coughing and straining. Other advantages cited for the LMA over the ETT included a decrease in the incidence of postoperative stridor and laryngospasm [54], although recent evidence disputes these advantages [55]. Indeed a recent review suggests that use of LMAs has not been widely accepted at least in North America. The French Association for Ambulatory Surgery (AFCA) and the French Society for Anesthesia, Intensive Care (SFAR) have published clinical practice guidelines, which recommend a cuffed endotracheal tube for tonsillectomy

[56]. We recommend the use of a cuffed endotracheal tube (ETT) for obese children during adenotonsillectomy, and a supraglottic airway device should be reserved for rescuing airway obstruction in these patients especially during a "can't intubate, can't ventilate" situation [57] or as an adjunct to the management of a difficult airway [14]. Specific advantages of cuffed ETT in this population include its ability to:

- Provide open access to the surgical site, potentially resulting in a more effective resection [58]. On the other hand, LMA takes up more room of oropharyngeal space which may already be narrow from excessive upper airway tissue, a relatively large tongue, and more fat tissue in obese patients.
- Provides definitive airway control that only rarely needs to be replaced. Several studies have reported rates of LMA failure during adenotonsillectomy with the need to convert to ETT, ranging from approximately 4% to 17% [54, 55, 59]. The conversion rate is lower (<1%) in nonobese children with normal airway anatomy and without OSA [59, 60]. Moreover, LMA may be difficult or impossible to place or seat in patients with very large tonsils.
- Adequately ventilate patients with positive pressure during both intraoperative and postoperative periods. Because of decreased lung compliance in obese children, a higher peak inspiratory pressure is warranted when positive pressure ventilation is needed, and this may not be possible with LMA. Obese children also require postoperative ventilation in ICU more often. LMA is not a secured airway device in this setting as it is placed in supraglottic area.
- Prevent the air leak and the consequent bubbling of gas in secretions and blood that can interfere with surgery as well as minimizes pollution by anesthetic gases and decreases the risk of an airway fire when electrocautery is used [28].

While an awake fiberoptic intubation is considered the gold standard approach in a patient with suspected difficult airway, this may not always be feasible in the pediatric patient. Compared to adults, pediatric patients are less likely to cooperate with awake airway instrumentation, so it is usually reserved for mature adolescents. Consequently, the majority of difficult pediatric airways are managed after induction of general anesthesia or deep sedation. Instillation of lidocaine jelly (2%) in the pharynx prior to inhalation induction will allow for early insertion of a supraglottic airway device (e.g., oral airway or an LMA) without inducing untoward airway responses or possibly laryngospasm. Video laryngoscopy has been studied in adult obese patients and may provide improved intubating conditions compared to a conventional laryngoscope [61]. Recent meta-analysis demonstrates that video laryngoscopy improved glottis visualization in pediatric patients with normal airways or with potentially difficult intubations but with the expense of longer time to intubation [62]. There are no specific studies in obese children. Further studies are needed to clarify the efficacy and safety of video laryngoscopy in this group of patient.

Baraka et al. described apneic oxygenation technique by nasopharyngeal oxygen supplementation in morbidly obese adult patients during elective intubation (general anesthesia with muscle relaxation). The time to oxygen saturation (SpO_2) less than 95% was significantly longer in the apneic oxygenation group treated with nasopharyngeal oxygenation (240 vs 145 s) [63]. Ramachandran et al. found similar results; the lowest SpO_2 level in the apneic oxygenation group was higher than the control group, and the onset of desaturation was delayed [64]. Another study demonstrated the novel use of apneic oxygenation via RAE tube placing in buccal area to adult obese patients during induction of anesthesia that clinically prolonged safe apnea times (750 vs 296 s) [65]. In a newly described technique, transnasal humidified rapid-insufflation ventilatory exchange (THRIVE), nasal high-flow oxygen insufflation has been shown to prolong the safe apnea time in healthy children but has no effect to improve CO_2 clearance [66]. Currently, there are no clear data to confirm, support, or refute its use in the pediatric population. However, it is simple to initiate, easy to administer, inexpensive (via high-flow nasal cannulas), readily available, and appears to have no reported complications; therefore it should be considered as a potentially useful technique.

Maintenance of Anesthesia

The main goal of anesthetic management for morbidly obese children is early and full recovery of consciousness and protective reflexes. To achieve this goal, multimodal analgesia and multimodal anesthesia are the keys and should be initiated from the moment of induction. Utilization of short acting anesthetic agents helps facilitate this process [22].

Of the currently available inhalational agents, both sevoflurane and desflurane have low blood–gas partition coefficients and low oil–gas solubilities resulting in a rapid onset and offset combined with a high degree of control over the anesthetic level obtained, as measured by the end-tidal concentrations. Sevoflurane provides a smooth induction of anesthesia as children who are scheduled for adenotonsillectomy have a high incidence of airway reactivity and laryngospasm. Desflurane used for maintenance in intubated patients provides a rapid emergence and recovery [67, 68] as shown in a recent meta-analysis exploring the differences in emergence between sevoflurane and desflurane which reported decreased time to extubation in favor of desflurane. N_2O is the inhalational agent with the lowest blood–gas solubility and a lipid solubility, less than Desflurane, and is being increasingly used in morbidly obese patients as a volatile-sparing adjunct. Its second gas effect during induction and emergence can accelerate wash in and wash out of volatiles [22]. However, it should not be used during airway surgery due to its combustibility.

Remifentanil allows the maintenance of a profound level of opioid effect without the prolonged apnea seen with longer-acting opioids, which is especially important for children with severe sleep apnea. Remifentanil may increase postoperative pain because of its central sensitization effect leading to increased opioid requirement and possibility of increased risk for postoperative respiratory depression [32].

Determining the optimal analgesic regimen for tonsillectomy in obese children can be even more complicated because children with high BMI appear to have increased early post-tonsillectomy pain, a phenomenon that currently lacks any solid explanation [69].

If muscle relaxant is used, full reversal of neuromuscular blockade is mandatory. Sugammadex has been shown to provide a safer and faster recovery (less time to reach a train-of-four ratio ≥ 0.9) from profound rocuronium-induced neuromuscular blockade than neostigmine did in adult patients with morbid obesity. Upon PACU arrival, level of SpO_2, ability to swallow ($p = 0.0027$), and ability to get into bed independently were better in patients who received sugammadex after bariatric surgery [70].

Perioperative Analgesia

Over the last decade, there has been a shift from opioids as the mainstay of perioperative analgesia to non-opioid regimens including dexmedetomidine, acetaminophen, NSAIDs, dexamethasone, and ketamine. Multimodal approach is the key to staying away from opioid-induced respiratory depression.

Acetaminophen It is commonly used as a component of multimodal analgesic approach in these children [71]. An intravenous formulation of acetaminophen is available in many countries, offering the theoretical advantage of greater predictability than the oral and rectal routes.

NSAIDS Despite concerns that the routine use of NSAIDs for adenotonsillectomy might increase the risk for post-adenotonsillectomy hemorrhage [72, 73], the AAO-HNS now recommends their use for postoperative analgesia. An audit of more than 4800 pediatric tonsillectomies in which the NSAIDs diclofenac and ibuprofen were routinely used reported a primary hemorrhage rate of 0.9% [74]. Because the effects of ketorolac on platelet function are reversible, the effect is dependent on the presence of ketorolac within the body [75]. Thus, unlike the effect of aspirin, this effect is short-lived. However, we recommend avoiding NSAIDs, especially ketorolac, *during* surgery. When used for postoperative analgesia, they should be administered after hemostasis is achieved [76] and should only be administered in consultation with the surgeon. NSAIDs and acetaminophen have been shown to be effective analgesics for post-tonsillectomy pain management [77], especially when they are used in alternating doses [78].

Steroids A single intraoperative dose of dexamethasone reduces post-adenotonsillectomy pain and edema when electrocautery has been used. The minimum morphine-sparing dose for dexamethasone is reported to be 0.5 mg/kg [79]. The use of dexamethasone is used to be controversial because of a possible linkage to post-tonsillectomy hemorrhage. In 2008 Czarnetzki et al. reported an increase in bleeding in children who had received dexamethasone up to 0.5 mg/kg (maximum 20 mg) [80]. However, these findings have been refuted by others [81–85]. The consensus opinion summarized in an editorial by Yee et al. in 2013 is that single intraoperative dose of dexamethasone does not cause clinically important hemorrhage following tonsillectomy. Single doses of dexamethasone have not been associated with aseptic necrosis of the hip or infections but have been responsible for precipitating the acute tumor lysis syndrome [86–88]. However blood glucose levels can increase after one dose of dexamethasone; thus it should be used cautiously in patients with history of diabetes or glucose intolerance.

Local Infiltration of Local Anesthetic Infiltration of local anesthetics into the tonsillar fossa during tonsillectomy is reported to decrease postoperative pain, but the pain relief is transient [89]. In addition, life-threatening complications have been reported after local anesthetic infiltration in the tonsillar fossa, including intracranial hemorrhage, bulbar paralysis, deep cervical abscess, cervical osteomyelitis, medullopontine infarct, and cardiac arrest. The risks associated with injection of local anesthesia in the tonsillar fossa may outweigh its potential benefits, particularly in inexperienced hands [90, 91]. Blockade of neural input to the upper airway dilator musculature in children with OSA is also problematic. Serious life-threatening complications, including severe upper airway obstruction (UAO) and pulmonary edema, have been reported after local anesthetics have been infiltrated in the tonsillar fossa to prevent pain after adenotonsillectomy. The pharynx in children with OSA is not only smaller in size, but also more collapsible, even during wakefulness, compared with those children who do not have OSA. Topical anesthesia applied to the mucosa of the pharynx of children with OSA reduces the caliber of the pharynx and may thereby compromise airway patency.

Dexmedetomidine An infusion of dexmedetomidine 1–2 mcg/kg iv over 5–10 min combined with an inhalation agent can provide satisfactory intraoperative conditions for adenotonsillectomy without adverse hemodynamic effects. In children with OSAS, postoperative opioid requirements are significantly reduced, and the incidence and severity of severe emergence agitation are reduced, with few children desaturating [92]. After larger doses of dexmedetomidine (2 and 4 mcg/kg), the opioid-free interval increases, and the postoperative opioid requirements decrease. However, duration of stay in the PACU is prolonged [93]. A meta-analysis of randomized controlled trials showed that intraoperative use of dexmedetomidine was as effective as opioids (fentanyl or morphine) in preventing postoperative pain and emergence agitation in children who had undergone tonsillectomy and adenoidectomy [94].

Ketamine Recent studies have found great success in adding ketamine to oral midazolam syrup for premedication to help reduce agitation and postoperative pain in the first 30 min following surgery [95]. Combination of single dose of ketamine (0.25 mg/kg iv) and acetaminophen (15 mg/kg iv) provided significantly better postoperative analgesia in children at 0.5 and 6 h after adenotonsillectomy than acetaminophen alone [96].

Codeine Once considered a “low-risk” oral opioid and commonly used for post-tonsillectomy pain, codeine now is not recommended because of its safety and efficacy profile. Respiratory arrest after codeine has been reported in both adults and children who demonstrate ultra-rapid metabolism of codeine. Whereas the ultra-rapid metabolizing genotype is present in 3% of Caucasians, it is present in 10–30% of Arabian and Northeast African populations. In contrast, almost 10% of children lack of metabolizing “CYP2D6” enzymes, rendering codeine an ineffective analgesic. The FDA recently required that the manufacturers of all codeine-containing products add a boxed warning to the labeling of their product that describes the risk posed by codeine after a child has undergone tonsillectomy or adenoidectomy and codeine use is contraindicated in such patients [28, 97].

Choice of Spontaneous vs Controlled Ventilation

Children with OSA have a diminished ventilatory response to CO2 and are more sensitive to opioids compared to others without OSA. Spontaneous respiration during maintenance of anesthesia enables an assessment of the response to small challenges of opioid analgesics and is usually recommended during adenotonsillectomy [29]. In this manner, the anesthesiologist can assess the sensitivity of the child with OSAS to opioids. Controlling respiration precludes such an evaluation. However, in morbidly obese children, there are several pathophysiologic changes of respiratory system including decreased chest wall compliance, decreased FRC from increased intra-abdominal pressure, and increased oxygen consumption. These changes contribute to higher rates of perioperative hypoxia from reduced oxygen reserves, more rapid desaturation, and increased work of breathing. Maintaining spontaneous breathing following induction of anesthesia in the supine position for this group of patients can be challenging. Pressure support ventilation mode preserves patient’s initiating effort to breathe while allowing positive pressure ventilatory support. PEEP of 5–10 cm H_2O, intermittent recruitment maneuver, and head-up position are recommended to prevent basal atelectasis [52].

Dexmedetomidine has the benefit of providing analgesia and sedation with minimal respiratory depression. Its use along with other non-opioid analgesics makes the objective of maintaining spontaneous respiratory effort for these obese children more plausible [34].

Emergence and Postoperative Case

Non-depolarizing muscle relaxant is rarely administered during routine adenotonsillectomy. However, in morbidly obese children, it may be given as a part of “balanced” anesthesia to prevent coughing, gaging, or movement. Full antagonism of neuromuscular blockade is mandatory as residual neuromuscular blockade in the recovery room will selectively depress the function of the upper airway dilators relative to the diaphragm, promoting collapse of the pharyngeal airway. In comparison with neostigmine, sugammadex can more rapidly reverse rocuronium-induced neuromuscular block regardless of the depth of the block [98]. It has been shown to provide a safer and faster recovery (less time to reach a train-of-four ratio ≥ 0.9) from profound rocuronium-induced neuromuscular blockade than neostigmine did in adult patients with morbid obesity. Upon PACU arrival, level of SpO_2, ability to swallow ($p = 0.0027$), and ability to get into bed independently were better in patients who received sugammadex after bariatric surgery [70, 99].

Extubation of the trachea should be performed when the child is fully awake with complete return of protective airway reflexes. Placement of a nasopharyngeal or oropharyngeal airway prior to extubation is sometimes useful. Intact airway and pharyngeal reflexes are of utmost importance in preventing aspiration, laryngospasm, and airway obstruction. After extubation, the child should remain in the tonsil position postoperatively while being carefully observed and monitored during transport to the recovery room. Lateral positioning has been shown to increase upper airway cross-sectional area and total upper airway volume when compared with the supine position [100]. Once patients can maintain adequate airway patency, they should be placed in the upright position to increase functional residual capacity (FRC) and reduce the risk of basal atelectasis.

Despite removal of the hypertrophied tonsils and adenoids, children with OSAS continue to demonstrate obstructive apnea and desaturation during sleep on the first night after adenotonsillectomy, with the frequency of the obstructive events and the severity of desaturation usually greater in those children with severe OSAS. This underscores the need to admit these children to a hospital for continuous overnight monitoring postoperatively. The majority of desaturation events on the first postoperative night are obstructive apnea. Statements from the American Academy of Pediatrics and the American Academy of Otolarygology–Head and Neck surgery now recommend admission to hospital following adenotonsillectomy for, respectively, an AHI >24 and an AHI >10 events per hour. Current pediatric tertiary care admission practices following adenotonsillectomy were recently published and show that 73% of respondents reported using some measure of obesity as a criterion for postoperative admission [101]. Fung et al. found that obese children were nearly 9 times more likely to have postoperative respiratory events, such as oxygen desaturation, airway obstruction, respiratory depression, cough, and bronchospasm, compared with their normal-weight counterparts. In obese children, of those experiencing desaturation events in the immediate postoperative period, 75% of them continued to experience respiratory events through the first postoperative night [102]. Therefore, it is prudent to observe the obese child overnight, especially if a preoperative PSG was not performed, owing to the uncertainty of the severity of the obstruction and degree of hypoxemia.

Morbidly obese children with severe OSA and complex medical diseases, who are critically dependent on the function of upper airway musculature, may benefit from delayed extubation. Acute relief of chronic UAO favors the exudation of intravascular fluid into the pulmonary interstitium and noncardiogenic pulmonary edema, which may present preoperatively, intraoperatively, and postoperatively. Supportive measures include the administration of oxygen, endotracheal intubation, mechanical ventilation with positive end-expiratory pressure, and administration of furosemide. Individuals with obstructive sleep apnea who use continuous positive airway pressure (CPAP) devices may benefit from the use of CPAP upon emergence by splinting open airways. In the past, it was generally felt that CPAP or BiPAP was contraindicated after surgery on the airway, following case reports in the ENT literature describing subcutaneous emphysema and pneumomediastinum/pneumothorax after T&A. Although there was no relationship to positive pressure airway support, the hypothetical risk was assumed. However, a retrospective study suggested that BiPAP is a safe and effective method of respiratory assistance for children after T&A [103]. In a study of 1735 consecutive pediatric patients undergoing tonsillectomy with or without adenoidectomy, Tweedie and colleagues reported that the odds ratio for obese patients requiring an unexpected PICU admission was 10.6 compared to nonobese patients [104].

Diagnostic Laryngoscopy and Bronchoscopy

Although diagnostic laryngoscopy and bronchoscopy procedures (DLB) are usually brief, the anesthetic management can be challenging in morbidly obese children with OSA because of a potential difficult airway and rapid desaturation. The anesthetic plan and goals should be discussed with endoscopists prior to induction, emphasizing obesity related comorbidities especially pulmonary and cardiac function as well as potential for a difficult airway. Anesthetic goals may include the following: (1) maintain spontaneous ventilation initially when surgeons may be attempting to evaluate vocal cord movement for dysfunction; (2) maintain a patent airway with an ability to provide controlled ventilation and, if needed, to ensure effective oxygenation and ventilation; (3) provide an adequately deep level of anesthesia; (4) prevent a laryngospasm; and (5) provide a rapid recovery of airway reflexes and ventilation.

Anesthesia for DLB in morbidly obese children can be done with total intravenous anesthesia (TIVA) technique or inhalational agents. It usually starts with an inhalational induction and then switches to TIVA during procedure when ventilation is intermittently interrupted, and it becomes difficult to maintain an appropriate depth of anesthesia with inhalational technique. A TIVA technique has the advantage that it can be given continuously during the procedure, resulting in a more stable level of anesthesia. A combination of local anesthetics deposited on the vocal cords with TIVA using propofol and dexmedetomidine is a common anesthetic regimen. Remifentanil and/or Ketamine titrated to effect are frequently used as supplements. Dexmedetomidine maintains spontaneous ventilation, airway patency, and tone, making it an ideal choice for dynamic upper airway evaluation even at higher doses (3 mcg/kg/h) in children with OSA [105, 106]. Recent study showed that, in adult patients with OSA, sedation with dexmedetomidine for sleep endoscopy comparing to with propofol resulted in slightly lower degree of upper airway narrowing, significant higher minimal oxygen saturation, and less number of patients with oxygen saturation <80% [107]. Small doses of ketamine (0.5–1 mg/kg) can be used to enhance analgesia and increase depth of anesthesia without further compromising the airway by muscle relaxation or suppressing respiratory drive [108]. A study showed that ketamine was accompanied by lower levels of upper airway dilator muscle dysfunction compared to the equi-anesthetic concentration of propofol, with preservation of ventilation with a wide dose range of ketamine [109]. A combination of ketamine and dexmedetomidine bolus followed by a dexmedetomidine infusion has been shown to provide sedation without exacerbating respiratory problems in children with Down syndrome and OSA [109]. The combination of dexmedetomidine and ketamine provided fewer oxygen desaturations to <85% compared with either propofol alone or sevoflurane plus propofol for drug-induced sleep endoscopy in children with persistent OSA despite surgical interventions (including previous tonsillectomy and adenoidectomy) [110]. Remifentanil infusion titrated of the patients' respiratory rates provide a good level of immobility while still permitting relatively rapid emergence. However, it frequently induces apnea and should be started at a very low dose due to sensitivity to opioids in morbidly obese children.

Due to their physiologic changes, rapid desaturation is expected in this patient population during DLB; therefore strategies to maintain oxygenation and ventilation are needed. There are various techniques that can be employed.

1. Spontaneously breathing with oxygen insufflation: Supplemental oxygen can be connected to the oxygen port on the surgical laryngoscope to provide oxygen to the oropharynx that is drawn into the lungs during spontaneous ventilation. Alternatively, an ETT connected to the anesthesia machine circuit can be placed in the surgeon's hand that is holding the laryngoscope with the distal opening of the tube in the posterior oropharynx. This technique should delay the onset of desaturation.
2. Apneic technique with intermittent mask ventilation and/or intubation: This technique will provide both oxygenation and ventilation, but surgical procedure is interrupted intermittently. It may be needed in patients with severe OSA who most likely would stop breathing or have significant hypoventilation during a deep plane of anesthesia. For patients who require prolonged surgical interventions, intermittent intubation may be more appropriate than mask ventilation.
3. Ventilation through the rigid bronchoscope: This technique can be done by attaching the anesthesia circuit with a flexible extension to the side port of the rigid bronchoscope. High

resistance may be encountered during positive pressure ventilation because of the length and the small diameter of the rigid bronchoscope. Moreover, the ventilation is more difficult and unlikely to be adequate due to leakage around the bronchoscope and low lung compliance in morbidly obese child.

4. Jet ventilation technique: This technique provides an unimpaired vision of laryngotracheal structures and access for surgical instruments. However, there are several potential problems related with it in morbidly obese children. Because of high inflation pressure requirement, barotrauma such as pneumothorax and pneumomediastinum and severe CO_2 retention can occur especially if there is an obstruction to expiratory flow [110]. There is also the possibility of hypoxemia, because the high-pressure oxygen entrains room air, diluting the inspired oxygen consumption. Therefore, jet ventilation has been considered a poor alternative for obese children. However, recent evidence has challenged this notion and reported the feasibility safety of jet ventilation in obese adult patients [110, 111].

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