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Chapter Objectives

1. Provide the anesthesiologist with a practical approach to the problems that require special consideration in morbidly obese patients.
2. Discuss comorbidities that should be evaluated preoperatively.
3. Discuss types of anesthetic agents.
4. Discuss how obesity affects airway management and how bariatric surgery affects fluid management.
5. Discuss postoperative considerations.

Introduction

Anesthetic management of the morbidly obese (MO) patient presenting for bariatric surgery differs significantly from that of the normal size patient undergoing similar procedures. Well-planned and rational management of patients undergoing bariatric surgery requires detailed knowledge of how morbid obesity affects anesthesia care. Not only the mechanical effects of the increased body size but also the physiological changes and comorbidities impact safe management and decision making by the anesthesiologist. The aim of this chapter is to provide a practical approach to the problems that require special consideration in morbidly obese patients.

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Preoperative Evaluation

Never assume that the primary care physician or surgeon has documented all comorbidities and coexisting diseases. A full assessment for medical conditions that can affect perioperative complications must be performed. Any organ dysfunction identified in the preoperative evaluation should be completely evaluated and optimized before proceeding with surgery.

Respiratory Issues Relevant to Anesthesia Management

The effect of obesity on the respiratory system decreases the margin of safety of anesthetic agents and increases the risk of respiratory failure in the perioperative period [1]. After bariatric surgery, respiratory failure is a life-threatening complication with a reported incidence of 1.35 % [2]. Risk factors that increase the likelihood of respiratory failure are congestive heart failure, open surgery, chronic renal failure, peripheral vascular disease, male gender, age >50 years, alcohol abuse, chronic lung disease, diabetes, and smoking [2].

At baseline, morbidly obese subjects may be mildly hypoxemic, with higher respiratory rates and lower tidal volumes. The compliance of the respiratory system is reduced and work of breathing increased. Functional residual capacity (FRC) and expiratory reserve volume (ERV) decrease exponentially with increasing body mass index (BMI), with the greatest rate of change in the overweight and mildly obese. In sitting subjects with a BMI of 30 kg/m², FRC and ERV are only 75 and 47 % of the values for a person with a BMI of 20 kg/m² [3]. In anesthetized supine patients, the effect of BMI on FRC is more pronounced and tidal volume is more likely to fall within closing capacity, promoting shunting [4]. In addition to the changes in respiratory mechanics and lung volumes, the prevalence of sleep apnea in bariatric patients can be as high as 75 % [5]. Of those with sleep apnea and severe obesity, up to 20 % may have the

obesity hypoventilation syndrome (OHS), which is characterized by daytime awake hypercapnia, hypoxemia, and elevated HCO_2^- [6]. It is important for anesthesiologists to recognize patients with OHS since it is associated with severe upper airway obstruction, restrictive lung disease, blunted central respiratory drive, pulmonary hypertension, and increased mortality. Before bariatric surgery, these patients should be referred to sleep medicine for polysomnography and positive airway pressure (PAP) titration. An echocardiogram should be performed to assess right ventricular function and pulmonary hypertension. Poor right ventricle function and high mean pulmonary artery pressures (>35 mmHg) are associated with an unacceptable perioperative anesthesia-related mortality risk. Perioperative precautions of OHS include prudent airway management, rapid emergence, monitoring for ventilatory impairment, and early resumption of PAP therapy.

The compromised respiratory status of the obese requires special precautions to prevent oxygen desaturation at induction of anesthesia, during surgery, and in the postoperative phase. After preoxygenation with 100 % oxygen and complete denitrogenation, an anesthetized supine paralyzed morbidly obese patient's oxygen saturation decreases from 100 to 90 % in about 2.5 min [7]. Premedication depresses spontaneous ventilation and should be minimized. Preoxygenation techniques delaying the onset of hypoxia should be used: the 25° head-up position may add a minute to the safe apnea time [8], and application of positive airway pressure during induction of anesthesia can increase safe apnea time by 50 % [9].

Immediately after induction of anesthesia, atelectasis develops mainly in the dependent lung. Atelectasis results in pulmonary shunting and hypoxemia. In addition, release of inflammatory cytokines associated with atelectasis may contribute to postoperative ventilator-associated lung injury such as pneumonia and respiratory failure. In the morbidly obese, ventilatory strategies to prevent atelectasis may require positive end-expiratory pressure (PEEP) values higher than 10 cm H_2O and recruitment maneuvers. Although high PEEP levels combined with a pneumoperitoneum will decrease venous return and can induce hypotension, in well-hydrated morbidly obese patients, PEEP levels up to 20 cm H_2O are tolerated [10].

Cardiovascular Issues Relevant to Anesthesia Management

The increased tissue mass of the morbidly obese needs to be perfused leading to an increased total blood volume. The total blood volume is increased, but on a per kg total body weight basis, the blood volume is actually decreased. Blood volume per kg total body weight (TBW) decreases exponentially from 70 ml/kg TBW at a BMI of 22 kg/m^2 to 40 ml/kg TBW at a BMI of 65 kg/m^2 (Fig. 8.1) [11]. If 70 ml/kg

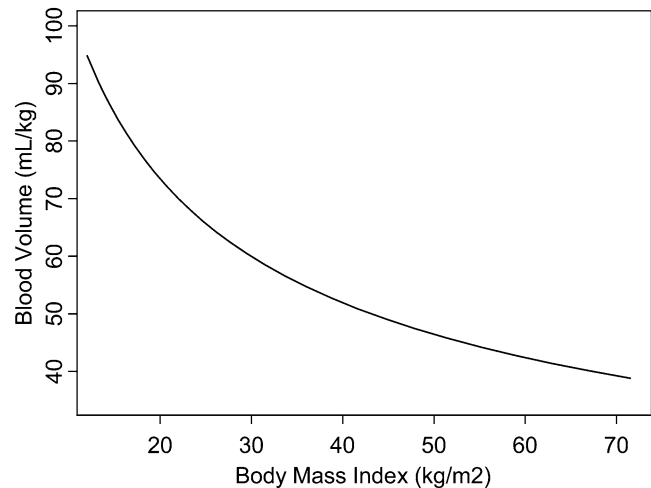


Fig. 8.1 Effect of BMI on blood volume in mL per kg TBW. Blood volume (mL per kg TBW) for a patient with a given BMI (BMI_p) can be calculated using the equation:

$$\frac{70}{\sqrt{\frac{\text{BMI}_p}{22}}}$$

TBW is mistakenly used for blood volume calculation, blood volume of the morbidly obese is overestimated, and undertransfusion of blood products may occur when significant blood loss during surgery is encountered. The increased total blood volume of the morbidly obese results in an increased cardiac output. Cardiac output increases from 4 L/min at a BMI of 20 kg/m^2 to more than 6 L/min at BMIs greater than 40 kg/m^2 . Cardiac output affects the early pharmacokinetics, the front-end kinetics of drug distribution and dilution in the first minutes after administration. An increased cardiac output decreases the fraction of drug distributed to the brain and increases the rate of redistribution, which will result in lower concentrations, faster awakening, and increased dose requirement. This phenomenon has important implications for the induction dose of intravenous anesthetic agents.

The most prevalent comorbidity in bariatric patients is hypertension. Obesity may lead to abnormal cardiac function through pathways that are associated with hypertension or independent of hypertension. The mechanisms of decreased cardiac contractility associated with obesity independent of hypertension are related to metabolic dysregulation but not completely understood. The increased body mass, the metabolic syndrome, insulin resistance, type 2 diabetes, and physical inactivity all contribute to systolic and diastolic dysfunction even in otherwise healthy young obese subjects, which may eventually progress to left and/or right heart failure. The combination of super obesity ($\text{BMI} > 50$ kg/m^2) with hypertension and diabetes is associated with a twofold increased risk of death and adverse cardiac events in the perioperative phase [12]. Congestive heart failure, peripheral vascular disease, and chronic renal failure are predictive

factors of increased in-hospital mortality after surgery. Obesity is also associated with an increased risk of atrial fibrillation and ventricular ectopy. Cardiac events can be a significant cause of 30-day mortality after bariatric surgery.

Pharmacological Considerations

Until recently, obese subjects have been routinely excluded from clinical trials to obtain regulatory approval for investigational drugs. This has resulted in package insert dosage recommendations based on total body weight, valid for normal-weight patients but not for the obese. Morbid obesity alters the pharmacokinetics and drug response of anesthetic agents. In addition, the decreased pulmonary and cardiac reserve of the morbidly obese decreases the margin of safety of anesthetic agents significantly. Therefore, incorrect dosing can increase the rate of perioperative complications.

Obesity is not only associated with an increase in tissue mass but also changes in body composition and tissue perfusion. Fat mass and lean body mass both increase, but the increase is not proportional. The percentage of lean body mass as a percentage of total body weight decreases (Fig. 8.2). The different ratio of lean body weight (LBW) to fat weight at different BMI will have a significant impact on drug distribution. Fat perfusion is also altered at different BMIs. At low BMIs fat is relatively well perfused; at high BMIs fat is poorly perfused. Because of the different ratio of fat to lean body weight at different BMIs and changes in fat perfusion, the effect of obesity on drug distribution into the different tissues is poorly understood.

The increased cardiac output of the morbidly obese increases the dose requirements of induction agents. In patients with normal cardiac function, cardiac output is highly

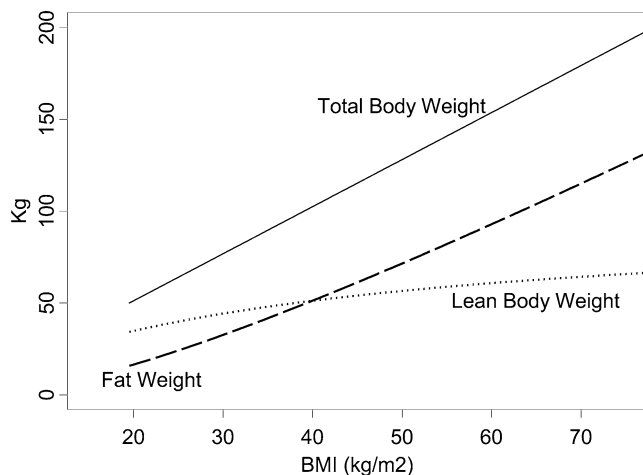


Fig. 8.2 Changes in body composition for a typical frame 160 cm tall female who increases her BMI. Lean body weight was calculated using the equations published by Janmahasatian et al. [24]. Fat weight was calculated by subtracting lean body weight from total body weight

Table 8.1 Recommended dosing scalars for morbidly obese patients

	Dosing scalar	Comments
<i>Induction agents</i>		
Thiopental	LBW	
Propofol	LBW	For continuous infusion or maintenance dosing TBW
Etomidate	LBW	Use in septic patients is controversial
<i>Opioids</i>		
Fentanyl	LBW	Titrate to effect
Alfentanil	LBW	
Sufentanil	LBW	
Remifentanil	LBW	TBW dosing may result in significant hypotension and/or bradycardia
<i>Muscle relaxants</i>		
Succinylcholine	TBW	The incidence of myopathy is low in morbidly obese patients
Rocuronium	LBW/IBW	IBW dosing results in shorter duration of action
Vecuronium	LBW/IBW	
Cisatracurium	LBW/IBW	
Atracurium	LBW/IBW	Fast administration may result in histamine release
Pancuronium	BSA	Do not use. Duration of action is too long

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

correlated to lean body weight, more so than total body weight or other variables. Therefore, lean body weight and cardiac output are more appropriate dosing scalars than total body weight. Total body weight dosing of induction agents will result in overdosing and side effects such as hypotension.

Numerous pharmacokinetic studies have shown that clearance, the most relevant pharmacokinetic parameter for maintenance dosing, is linearly related to lean body weight but not total body weight. This implies that lean body weight is the appropriate dosing scalar, not only for determining induction and loading doses, but also for maintenance doses. Recommended dosing scalars for several anesthetic agents are summarized in Table 8.1.

Induction Agents

Thiopental

Although thiopental is part of the World Health Organization's "Essential Drugs List," its use in the United States has been largely replaced with propofol. Nevertheless, thiopental is an ideal anesthesia induction agent with arguably less side effects than propofol. Immediately after intravenous (IV) administration, thiopental distributes to highly perfused tissues such as the brain, lung, liver, heart, kidney, gut, and

pancreas. After an anesthetic induction dose, redistribution into muscle depletes thiopental from the brain and terminates the anesthetic effect within 5–10 min. The increased cardiac output associated with morbid obesity has a significant effect on thiopental dose requirement. After a thiopental induction dose of 250 mg, the higher cardiac output of a morbidly obese patient results in peak arterial concentrations up to 50 % lower than those of a lean subject. Thiopental dose adjusted according to lean body mass or the increased cardiac output results in the same peak plasma concentration as for a normal size person.

Propofol

In current practice, propofol is the induction agent of choice for obese patients. Cardiac output has a significant effect on peak plasma concentration and duration of effect. After a bolus dose for induction of anesthesia, propofol's peak plasma concentration is inversely related to CO. In addition, a higher CO is associated with a faster wake-up time. For COs of 8.5, 5.5, and 2.5 L/min, recovery of consciousness is predicted to occur at 2.9, 8.6, and 18.7 min, respectively. CO does not affect onset time. LBW is a more appropriate weight-based scalar than TBW for propofol induction of general anesthesia in MO patients. MO patients in whom anesthesia was induced with propofol dose based on LBW required similar doses of propofol and had similar times to LOC compared to nonobese control patients given propofol based on TBW.

Etomidate

Etomidate is less likely to cause a significant decrease in blood pressure than thiopental or propofol. Thus, in patients with significant heart disease or hemodynamically unstable patients, anesthetic induction with etomidate may be a better choice. The pharmacology of etomidate in obese patients has not been studied, but an induction dose based on lean body mass and cardiac output can be justified given the pharmacokinetic and pharmacodynamic similarities of etomidate, thiopental, and propofol.

Etomidate transiently suppresses corticosteroid synthesis in the adrenal cortex by reversibly inhibiting 11-beta-hydroxylase. This suppressant effect on steroid synthesis is probably clinically insignificant after a single dose used for induction of anesthesia. However, in patients with sepsis, the use of etomidate for induction of anesthesia is controversial. Other side effects are pain at injection, myoclonus, and a high incidence of postoperative nausea and vomiting.

Dexmedetomidine

Dexmedetomidine is used as a sedative agent with both anxiolytic and analgesic effects. Dexmedetomidine is a selective alpha₂-adrenoreceptor agonist. Respiratory depression is minimal but dexmedetomidine potentiates the respiratory depressant effect of opioids and benzodiazepines. The short distribution half-life (8 min) and relatively short elimination half-life (2 h) make it suitable for titration by continuous infusion. The sympatholytic effect of dexmedetomidine decreases norepinephrine release and will decrease arterial blood pressure and heart rate. This may result in severe hypotension in hypovolemic patients and severe bradycardia in patients with heart block. Another side effect is dry mouth, which when used during fiberoptic intubation is an advantage. Postoperatively, dexmedetomidine reduces shivering. During open gastric bypass surgery when used instead of fentanyl to supplement desflurane, a loading dose of dexmedetomidine, 0.5 mcg/kg, given over 10 min followed by an infusion of 0.4 mcg/kg/h, resulted in significantly lower arterial blood pressure and heart rate, shorter time to tracheal extubation, lower pain scores, and less use of morphine and antiemetics in the postanesthesia care unit (PACU). For adjunctive use during laparoscopic bariatric surgery, a lower infusion rate (0.2 mcg/kg/min) is recommended to reduce the risk of cardiovascular side effects.

Opioids

In contrast to fentanyl and its analogues alfentanil, sufentanil, and remifentanil, the longer-acting opioids morphine and hydromorphone are not potent enough to effectively block somatic and autonomic responses during surgery. In addition, the drowsiness and sleepiness at emergence associated with morphine and hydromorphone administration are unwanted in the morbidly obese. Therefore, their use during surgery is best avoided.

Fentanyl

Fentanyl has a fast onset of effect (5 min) and effectively blocks somatic and autonomic responses during surgery. Fentanyl is probably the most commonly used opioid during bariatric surgery. The higher cardiac output in obese patients will result in significantly lower fentanyl concentrations in the early phase of distribution. Also later on, pharmacokinetic parameters of normal size persons will overpredict measured fentanyl concentrations in obese patients. The clearance of fentanyl is higher in obese patients and increases

nonlinear with increasing TBW, but linear with lean body weight (LBW). These data suggest loading and maintenance doses of fentanyl should be based on LBW. However, obesity increases the probability of respiratory depression in the perioperative period, and fentanyl and other opioid administration should be carefully titrated according to individual patient's need.

Sufentanil

Sufentanil is the most potent opioid. It is highly lipophilic and has an onset time of approximately 5 min. Like fentanyl, pharmacokinetic parameters of normal size persons will overpredict measured sufentanil concentrations in morbidly obese patients.

Alfentanil

Alfentanil has a fast-onset time of approximately 1 min. The higher cardiac output in obese patients will result in significantly lower alfentanil concentrations in the early phase of distribution. Alfentanil is less lipid soluble than fentanyl or sufentanil and has a smaller volume of distribution. No data on the effects of obesity on the pharmacokinetics of alfentanil have been published.

Remifentanil

Remifentanil's physicochemical properties result in a fast-onset time of approximately 1 min. Bolus administration in awake patients may result in severe bradycardia, hypotension, and muscle rigidity. Plasma and tissue esterases hydrolyze remifentanil rapidly, resulting in an extraordinary high clearance (3 L/min) unaffected by hepatic or renal insufficiency. The fast-onset time and high clearance make remifentanil especially suitable for administration by continuous infusion. Volumes and clearances not normalized for weight are similar in obese and nonobese patients and do not correlate with TBW but correlate significantly with LBW. Therefore, in the obese, dosing of remifentanil based on TBW will result in concentrations higher than those needed for clinical purposes and an increased incidence of side effects such as hypotension and bradycardia. Remifentanil dosing based on LBW will result in plasma concentration similar to those in normal-weight subjects when dosed according to TBW. After discontinuation of the administration, drug effect terminates rapidly within 5–10 min. Therefore, when postoperative pain is anticipated,

alternative analgesics should be administered prior to remifentanil's discontinuation.

Inhaled Anesthetics

Isoflurane

The solubility of inhaled anesthetic agents in fat and the increased fat mass of the obese patient would theoretically result in an increased anesthetic uptake, especially with more fat-soluble anesthetics such as isoflurane. However, blood flow per kg of fat tissue decreases significantly with increasing BMI, therefore limiting uptake. In addition, the time constants (the time to reach 63 % of equilibrium) for equilibrium with fat are long (2,110 and 1,350 min for isoflurane and desflurane, respectively). The decreased fat perfusion and relatively long time constants will diminish the effect of the increased fat mass on the uptake of inhalational agents. During routine clinical practice, the effect of BMI on the uptake of desflurane and the more lipid soluble isoflurane was clinically insignificant.

The concern that isoflurane prolongs emergence from anesthesia in obese patients due to its lipid solubility could also not be substantiated. Obese and nonobese patients emerged from anesthesia similar times (7 min) after 0.6 MAC isoflurane administration for procedures lasting 2–4 h. After termination of isoflurane administration, the time to extubation can be decreased significantly by increasing alveolar ventilation using an isocapnic hyperpnea method.

Desflurane

The effect of BMI on desflurane uptake is insignificant, and obese and nonobese patients emerge from anesthesia equally rapidly (4 min) after 0.6 MAC desflurane administrations for procedures lasting 2–4 h. Several studies in obese patients have compared desflurane and sevoflurane with variable results, finding either a faster awakening with desflurane or no difference.

Sevoflurane

Sevoflurane appears to provide a slightly more rapid uptake and elimination of anesthetic in morbidly obese patients than does isoflurane. Fluoride, a metabolite of sevoflurane, in concentrations greater than 50 mmol/L, can be nephrotoxic. In addition, sevoflurane is degraded to compound A by carbon dioxide absorbers containing a strong base such as

barium hydroxide lime or to a lesser extent by soda lime. Reductions in fresh gas flow as well as an increase in temperature in the gas mixture will increase compound A concentrations. Albuminuria, glycosuria, and enzymuria are associated with inhaled doses of compound A greater than 160 ppm/h. In the few studies in patients with renal impairment, no evidence of further worsening of renal function could be demonstrated after sevoflurane administration. However, the safety of sevoflurane in patients with impaired renal function is unclear.

Muscle Relaxants

Succinylcholine

Succinylcholine is a depolarizing muscle relaxant. It is a nicotinic acetylcholine receptor agonist causing fasciculations followed by flaccid paralysis by depolarization of the motor end plate. Succinylcholine has the fastest onset and shortest duration of action of all muscle relaxants—excellent properties to achieve intubation of the trachea rapidly. If difficulty is encountered managing the airway of the patient, return of neuromuscular function and spontaneous ventilation will occur within 5–7 min. Maximum effect and duration of action are determined by the extracellular fluid volume and elimination by the plasma enzyme butyrylcholinesterase (also known as pseudocholinesterase). Extracellular fluid volume and activity of butyrylcholinesterase both increase with increasing BMI. Therefore, morbidly obese patients have larger succinylcholine requirements than normal size patients. Succinylcholine, 1 mg/kg total body weight, will result in complete neuromuscular blockade and excellent intubation conditions in the obese. Lower doses are associated with poor intubating conditions due to incomplete neuromuscular block. Succinylcholine use is associated with increases in potassium and myalgia. The incidence of succinylcholine-induced myalgia is low in morbidly obese patients.

Rocuronium

Rocuronium is a nondepolarizing muscle relaxant that can be used as an alternative to succinylcholine for rapid sequence intubation. A dose of 1.2 mg/kg ideal body weight (IBW) provides excellent or good intubating conditions 60 s after administration. However, the time to reappearance of T1 is 52 min. Rocuronium maintenance dosing based on lean body weight has not been studied, but dosing on the basis of ideal body weight is appropriate. Maximum effect and recovery times of rocuronium and all other muscle relaxants are

highly variable; therefore continuous monitoring of the degree of neuromuscular blockade is recommended.

Vecuronium

The pharmacokinetic parameters uncorrected for weight are similar between obese and nonobese subjects. In obese subjects receiving 0.1 mg/kg vecuronium based on TBW, recovery times from neuromuscular blockade were approximately 60 % longer than in normal-weight control subjects. The prolonged recovery from neuromuscular blockade in the obese patients can be explained by the larger dose of vecuronium. The similar pharmacokinetics will result in higher vecuronium plasma concentration in the obese. With higher doses and higher plasma concentrations, recovery from neuromuscular blockade will occur at a time when plasma concentration decreases more slowly, instead of the more rapid decline after a smaller dose when recovery occurs earlier during the distribution phase. To avoid overdose in the obese, administering vecuronium on the basis of IBW is recommended.

Cisatracurium

Cisatracurium is eliminated via Hoffman degradation, a pathway independent from kidney or liver function. As expected, TBW dosing results in a prolonged duration of action when compared with a control group of normal body weight patients. When administered to morbidly obese patients based on IBW, the duration of action of cisatracurium was decreased when compared to normal size patients.

Pancuronium

Obese patients require significantly more pancuronium than nonobese patients to maintain a constant 90 % depression of twitch height. When the pancuronium dose is normalized for body surface area, there is no difference in dose requirement. Since body surface area and extracellular fluid volume are correlated, the greater amount of pancuronium necessary to produce adequate muscle relaxation in the morbidly obese is probably related to the increase in extracellular fluid volume that occurs with increasing obesity. The kidneys excrete the majority of pancuronium and its active metabolites. In the morbidly obese patient, the shorter-acting nondepolarizing neuromuscular blockers such as rocuronium, vecuronium, or cisatracurium are a better choice instead of the long-acting pancuronium to avoid residual postoperative residual neuromuscular blockade.

Reversal Agents of Neuromuscular Blockade

Rapid and complete recovery from neuromuscular blockade is particularly important in the morbidly obese patient. Residual neuromuscular blockade will further compromise respiratory function in the immediate postoperative phase.

Neostigmine

The dose-response relationship of neostigmine for neuromuscular blockade reversal in morbidly obese patients has been poorly studied. When vecuronium is reversed with neostigmine at 25 % recovery of twitch height, there is no difference between normal size and morbidly obese patients in time to a recovery of train-of-four (TOF) ratio to 0.7 (3.8–4.8 min). However, recovery time to adequate reversal (a train-of-four ratio of 0.9) is four times slower in morbidly obese patients (25.9 versus 6.9 min). The recommended dose of neostigmine is 0.04–0.08 mg/kg, not to exceed a total dose of 5 mg. A deep neuromuscular block (TOF ratio of 0) cannot be reversed with neostigmine.

Sugammadex

Sugammadex is the first selective relaxant-binding agent specifically designed to bind and encapsulate rocuronium and vecuronium. It can provide immediate reversal of an intubating dose of rocuronium. The muscle relaxant is bound with high affinity within sugammadex's core and cannot bind to the acetylcholine receptor at the neuromuscular junction. The bound complex is excreted by the kidneys at a rate equal to the glomerular filtration rate. Unlike the acetylcholinesterase inhibitor neostigmine, sugammadex has no effect at the receptor level, and there is no need to coadminister antimuscarinic agents such as atropine or glycopyrrolate.

Sugammadex was approved for use in the European Union in 2008, but the US Food and Drug Administration (FDA) rejected the application in that same year because of concerns regarding possible hypersensitivity and allergic reactions. It is not approved for use in the United States at this time.

Monitoring

In the relatively healthy patient undergoing bariatric surgery, noninvasive monitoring during anesthesia will suffice. There are no data showing that invasive monitoring improves outcome in morbidly obese patients without advanced cardiac or pulmonary disease [13].

During surgery, a combination of lead II and lead V5 electrocardiographic monitoring has a sensitivity of 80 % to detect myocardial ischemia. Lead V4 and V5 monitoring has a sensitivity of 90 %. The best combination is V4, V5, and lead 2 monitoring, resulting in a sensitivity of 98 %. Cardiac abnormalities such as rhythm and conduction problems occur frequently in the morbidly obese. Atrial fibrillation is the most commonly occurring abnormal rhythm, especially in patients with obstructive sleep apnea (OSA). If during surgery or in the postoperative phase atrial fibrillation develops, atrial distension due to fluid overload can be the causative factor. Prolonged QT interval syndrome is a precursor of torsades des pointes, which can result in sudden cardiac death. Many drugs used in the perioperative phase such as ondansetron, sevoflurane, and methadone prolong the QT interval and should not be used in patients with prolonged QT interval syndrome.

A well-fitting blood pressure cuff encircling at least 75 % of the arm should be used to obtain reliable blood pressure measurements. A blood pressure cuff that is too large will underestimate blood pressure. A cuff that is too small will overestimate blood pressure. Special conical-shaped cuffs for morbidly obese patients are available. If a blood pressure cuff cannot be fitted on the upper arm, a standard blood pressure cuff placed on the forearm is a useful alternative. Lower arm measurements overestimate blood pressure. Noninvasive blood pressure measurements can be difficult to obtain, and the threshold to place an intra-arterial catheter should be low since invasive blood pressure measurement is accurate and complications of radial arterial line placement are rare.

The recommendation that a central venous line should be inserted routinely in obese patients is not valid. Peripheral venous access can be more difficult, but this is not a reason to place a central line. If placement of a peripheral venous catheter is problematic, ultrasound can be used to locate a peripheral vein before placement of a central venous line is attempted. Central venous access via the internal jugular vein is associated with a lower complication rate than subclavian vein puncture. Positioning the patient on a ramp similar to the positioning used for tracheal intubation with a roll under the shoulders will maximize neck exposure and facilitate placement. Thereafter, the patient can be placed in Trendelenburg position as tolerated. Insertion of a central venous catheter under ultrasound guidance facilitates correct placement and is currently the recommended approach [14].

The value of the central venous pressure (CVP) measurement does not necessarily reflect adequacy of circulating blood volume or response to fluid loading. A decreased CVP can reflect venodilation or hypovolemia. An increased CVP can reflect decreased cardiac pump function, increase in thoracic pressure and/or pericardial pressure, or increased pulmonary artery resistance. In contrast to the CVP pressure readings, the shape of the CVP waveform can be highly diagnostic.

For example, the presence of large v waves, which are diagnostic for tricuspid regurgitation, may indicate the presence of pulmonary hypertension and right heart failure.

Intravascular volume status is difficult to assess in obese patients. Pulse pressure variation, the decrease in arterial pulse pressure with positive pressure ventilation, is a more reliable indicator of hypovolemia than CVP. During inspiration of controlled ventilation, the great veins entering the heart are compressed resulting in a reduction of right ventricle preload and an increase in afterload. The decreased preload and increased afterload decreases the stroke volume of the left ventricle at the end of the expiration cycle. When this is exaggerated, the blood volume of the patient is contracted and a fluid bolus will improve cardiac output. Commercial devices are being marketed that provide real-time changes in pulse pressure variation.

Pulmonary artery pressure monitoring has fallen in disfavor because it is a poor indicator of left ventricle preload or circulating blood volume, but it is still being used to assess pulmonary hypertension.

Transesophageal echocardiography (TEE) is an invaluable tool to assess the possible cause of sudden intraoperative cardiac or hemodynamic instability such as myocardial ischemia associated with wall motion abnormalities, emboli, and hypovolemia. TEE cannot be used routinely during bariatric surgery because the ultrasound probe is in the surgical field.

The degree of neuromuscular blockade should be monitored during surgery. During surgery, train-of-four monitoring (TOF) is used to guide the administration of neuromuscular blocking agents. At the end of surgery, the TOF ratio is used to guide administration of reversal agents. A deep neuromuscular block (TOF ratio of 0) cannot be reversed with neostigmine, and reversal should be delayed until a TOF count of 2 is observed. The administered dose of neostigmine should not exceed 5 mg, and the trachea should not be extubated with a TOF ratio of <0.9.

Electroencephalographic-based brain function monitors are being used to guide administration of anesthetic agents and to prevent awareness. The efficacy of these monitors is controversial, and routine use of brain function monitoring during surgery is not supported by data. However, its use is recommended in cases where a high risk for awareness may be suspected. Administration of nitrous oxide, ketamine, isoflurane, or halothane can be associated with a paradoxical increase in BIS.

A Foley urinary catheter may be placed before any major surgery; but not required if the surgery is anticipated of short duration and routine. A low urine output may be encountered during laparoscopic bariatric surgery. Pneumoperitoneum decreases urine output by increasing ADH, aldosterone, and plasma renin activity.

Preoperative Sedation

For most patients, premedication with sedatives should be used with caution. Respiratory depression caused by benzodiazepines and opioids is more pronounced in the morbidly obese, especially in those with obstructive sleep apnea. The upper airway collapsibility of the morbidly obese combined with the decreased arousal response to airway occlusion makes these patients particularly sensitive to drug-induced respiratory depression. Benzodiazepines decrease upper airway muscle activity with consequent obstruction and cause central apnea during the initial post-administration minutes. If very anxious patients need premedication, small doses of midazolam can be administered upon transport to the operating room under continued visual monitoring and verbal communication during transport. Administration of oxygen during transport is recommended.

In the operating room, it is practical to have unpremedicated patients climb off the gurney and then position themselves on the operating room table.

Airway Management

According to recent data from the American Society of Anesthesiologists Closed Claim Database, almost 40 % of adverse airway events during induction of anesthesia occurred in obese patients, with a significant proportion resulting in permanent brain damage or death [15]. This is not surprising since inability to mask ventilate and intubate the morbidly obese patient will result in rapid development of hypoxemia. An understanding of the different requirements for airway management and adequate preparation is vital to avoid untoward events.

The supine position, routinely used for induction of anesthesia in nonobese patients, is not appropriate for the morbidly obese patient. The supine position will decrease the functional residual capacity further and will increase the intra-abdominal pressure resulting in restriction of the diaphragmatic movement with respiration. The torso of the morbidly obese should be elevated 30–45° prior to induction of anesthesia. Offsetting the mass loading of the abdomen and chest will increase the FRC, will decrease the restrictive component of the lung function, and will increase compliance. Therefore, elevation of the torso of the morbidly obese not only will improve the ability to ventilate the lungs by bag and mask but also will increase the time before desaturation starts to occur when there is an inability to manage the airway.

The standard “sniffing position” for tracheal intubation, which results in optimal alignment of axes of head and neck in the nonobese, is inadequate for the morbidly obese.

Fig. 8.3 Ramped position for tracheal intubation



A “ramped” position, with the patient’s upper body, head, and neck elevated until the external acoustic meatus and the sternal notch are in horizontal alignment, results in optimal position for tracheal intubation (Fig. 8.3). It also provides increased submandibular space facilitating manipulating the laryngoscope handle and laryngoscopy. Obesity itself is not an independent risk factor for difficult tracheal intubation, but obese patients with a large neck circumference, excessive pretracheal adipose tissue, and high Mallampati classification do have a higher probability of difficult intubation. Obesity and obstructive sleep apnea are independent risk factors for difficult mask ventilation but not for difficult intubation. Since facial hair can make ventilation of the lungs by bag and mask ineffective, it is appropriate to ask patients to shave beards preoperatively. When very difficult mask ventilation and/or tracheal intubation is suspected, awake fiberoptic intubation is the technique of choice. Spontaneous ventilation and airway patency will be maintained in the awake patient, assuming sedatives are carefully titrated—keeping in mind that even small amounts may result in airway obstruction. Adequate topical anesthesia of the larynx and pharynx and gentleness will result in intubation with minimal discomfort for the patient. Visualization of the larynx may be difficult due to airway narrowing by redundant folds of fat tissue. In a sitting patient, the pharyngeal space will be increased, and instructing the patient to protrude the tongue will further increase the diameter of the airway. Several reports have described the use of a laryngeal mask airway in an awake patient to open the surrounding tissues permitting easier visualization of the vocal cords and passage of the fiberoptic.

Aspiration Risk

The traditional belief that obese patients are at higher risk for aspiration at induction of anesthesia is unfounded. The volume of gastric content is not greater in fasted obese patients when compared to normal-weight subjects, and gastric emptying is not delayed, except in the setting of obesity-related disease as noted below. In fact, the proportion of high-volume low pH gastric content in obese unpremedicated subjects is lower (26.6 %) when compared to normal-weight patients (42 %).

Patients with comorbid conditions such as symptomatic gastroesophageal reflux disease, diabetes mellitus, and gastroparesis are at increased risk for gastric acid aspiration. A rapid sequence induction with cricoid pressure should be performed in these patients as well as in all patients that underwent a gastric banding procedure.

Pneumoperitoneum: Implications for Ventilation, Hemodynamics, and Urine Output

After insufflation of the abdomen, the increased intra-abdominal pressure and the increased absorption of CO₂ account for the majority of physiological alterations. The diaphragm moves in cephalad direction, which may result in migration of the endotracheal tube in the right main stem bronchus. High peak inspiratory pressures followed by hypoxemia and hypotension will result if this phenomenon is not recognized and corrected in a timely fashion.

Appropriate ventilatory adjustments can eliminate most of the absorbed CO₂ and prevent acid-base disturbances.

Upon insufflation heart rate and blood pressure typically increase; however, some patients may experience vagal-mediated bradycardia due to peritoneal stretching—a phenomenon typically short lived and relieved with peritoneal desufflation and administration of IV atropine. In morbidly obese patients, CO decreases with insufflation, while systemic vascular resistance, pulmonary vascular resistances, mean arterial pressure, right atrial pressure, and pulmonary capillary wedge pressure increase. In general, the impact of pneumoperitoneum on the cardiovascular system of the morbidly obese is well tolerated.

A decrease in renal perfusion occurs with pneumoperitoneum as well as increased release of antidiuretic hormone, plasma rennin activity, and serum aldosterone, resulting in water retention and a rapidly decreasing urine output. The extent of intraoperative oliguria is directly related to the extent of increased intra-abdominal pressure. Despite the hormonal changes and transient oliguria, clinically significant renal impairment as measured by serum creatinine does not occur after laparoscopic gastric bypass with insufflation pressures not exceeding 15 mmHg. However, in patients with preexisting renal impairment, minimal insufflation pressure and adequate IV hydration should be instituted to avoid further exacerbation of the renal insufficiency.

Effects of pneumoperitoneum on hepatic blood flow and function are similar to those of the kidneys and transaminase levels rising as much as sixfold 24 h after surgery. These effects may be enhanced in morbidly obese patients because many have underlying hepatic disease.

During open abdominal surgical procedures, reversed Trendelenburg position, >10 cm PEEP, and recruitment maneuvers can dramatically improve oxygenation in the morbidly obese. During laparoscopic procedures these measures are significantly less effective.

Use of sequential compression devices (SCDs) in combination with pneumoperitoneum is associated with a significant improvement in CO, stroke volume, portal venous and hepatic arterial blood flow, and marked improvement in renal perfusion, urine output, and systemic vascular resistance.

Fluid Management

The morbidly obese patient has an increased total blood volume (see Cardiovascular Issues Relevant to Anesthesia Management), but on a per kg total body weight basis, the blood volume is actually decreased.

Generous IV fluid administration (15–40 ml/kg total body weight) during surgery decreases the incidence of postopera-

tive nausea and vomiting and may decrease the incidence of rhabdomyolysis.

In the nonobese surgical population, a perioperative positive fluid balance of +5 l or more is associated with intra-abdominal hypertension and an incidence of intra-abdominal compartment syndrome as high as 25 %. Intra-abdominal hypertension is defined as an intra-abdominal pressure >12 mmHg; abdominal compartment syndrome is defined as an intra-abdominal pressure >20 mmHg with evidence of end-organ dysfunction. MO patients have higher baseline intra-abdominal pressure than normal-weight individuals, but not in the range of intra-abdominal hypertension. This baseline of higher intra-abdominal pressure combined with fluid administration and pneumoperitoneum predisposes the morbidly obese patient to intra-abdominal compartment hypertension and compartment syndrome. A judicious plan for perioperative IV fluid management is required.

Postoperative Considerations

In laparoscopic bariatric surgery, a deep neuromuscular block is needed to ensure an adequate surgical field. After completion of surgery before tracheal extubation is attempted, it is imperative to completely reverse the neuromuscular block. Even minimal residual paralysis causes retroglossal and retropalatal narrowing during inspiration, which may result in upper airway collapse.

Use of continuous positive airway pressure (CPAP) reduces the risk for atelectasis, and noninvasive ventilation can be used as a prophylactic and/or therapeutic tool to improve gas exchange postoperatively. There is concern CPAP may increase the likelihood of an anastomotic leak by air forced into the gastric pouch. However, in a recent study, changes in transmural gastric pouch pressure with the application of CPAP did not occur [16].

The American Society of Anesthesiologists (ASA) practice guidelines for the perioperative management of patients with OSA recommended that patients with OSA treated with CPAP should continue CPAP as soon as feasible after surgery [17]. The same guideline recommends that patients with OSA be monitored for 3 h longer than their non-OSA counterparts before discharge from the PACU. The recommendations for increased monitoring are based on expert opinion and not scientific evidence. The same guidelines caution performing upper abdominal laparoscopic surgery in an outpatient setting for patients with known or suspected OSA. In a series of 746 patients with obstructive sleep apnea after ambulatory laparoscopic gastric banding, 40 % did have an incidence of hypoxia in either the OR or PACU [18]. However, there were no incidences of respiratory failure or tracheal reintubation.

Postoperative Nausea and Vomiting

Bariatric surgery is associated with a high incidence of postoperative nausea and vomiting (PONV). Besides the surgery itself, obesity, female sex, a history of PONV, and motion sickness are known risk factors. Opioids, volatile anesthetics, and nitrous oxide all have dose-related emetogenic effects. Prevention of PONV is important since retching may jeopardize the integrity of the surgical anastomoses. The most commonly used antiemetic agent for the prevention of PONV is the serotonin antagonist ondansetron, with a half-life of 4 h. This short half-life makes the efficacy of ondansetron for longer-lasting prophylaxis, such as in the ambulatory surgery setting, questionable. The incidence of post-discharge nausea and vomiting (PDNV) after ambulatory surgery is higher than PONV and has been reported to be as high as 50 % in patients who did not experience PONV.

Besides adequate hydration with intravenous fluids, antiemetic strategies covering a longer duration should be employed [19]. Multiple agents with different mechanisms of action (multimodal therapy) are more effective than a single agent. Dexamethasone, 8 mg, intravenously administered at the beginning of surgery combined with the transdermal cholinergic antagonist scopolamine is an effective longer-lasting strategy. For patients with several risk factors, the new long-acting 5HT₃ antagonist palonosetron could be added. A single dose of palonosetron, 0.075 mg IV, decreases the incidence of PONV during a 3-day period. For patients with a history of intractable nausea and vomiting, the neurokinin-1 receptor antagonists aprepitant, 40 mg p.o., administered before surgery could be added as the 4th antiemetic and could be continued in the postoperative period. Non-pharmacological methods such as acupuncture and acupressure have limited efficacy, but could be worthwhile additions.

Postoperative Analgesia

Adequate postoperative pain relief is critical for patient comfort, pulmonary toilet, and early ambulation. Postoperative analgesia must be balanced to avoid opioid-related complications like PONV, sedation, ileus, and respiratory depression. The laparoscopic approach provides substantial benefit with less postoperative pain and medication use.

Postoperative oral administration of analgesics can be utilized in the ambulatory surgery setting, and oral absorption of drugs is essentially unchanged in obese patients with liquid preparation being best tolerated. The most common analgesic drugs given orally are nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids. NSAIDs are not generally

given due to potential risk of bleeding, particularly for surgical staple lines. Fentanyl is a potent opiate analgesic that can be delivered transdermally via a skin patch; however, the fentanyl patch should not be given in the postoperative setting, given its inability to titrate and that fentanyl absorption continues up to 17 h after the patch is removed. For the bariatric patient, intramuscular injection of analgesic drugs is not recommended, given this route's unpredictable and less efficient effect.

Patient-controlled analgesia (PCA) was developed to allow IV administration of analgesics in an incremental fashion, so that respiratory depression and heavy sedation could be avoided. PCA use is highly recommended for the morbidly obese patient [20]. Additionally, bupivacaine infusion devices for continuous postoperative infiltration of the surgical wound have been developed to avoid the risk of respiratory depression associated with opioids. Mixed results have been seen for potential benefits of heating and humidifying carbon dioxide (CO₂) insufflation for postoperative pain relief in laparoscopic surgery. The European Association for Endoscopic Surgery practice guidelines states that "the clinical benefits of warmed, humidified insufflation gas are minor and contradictory" [21]. Theoretically, intraperitoneal (IP) administration of local anesthetics can provide analgesia without opioid-related complications. A single randomized clinical trial examined the use of continuous IP infusion in laparoscopic adjustable gastric banding [22]. A statistically significant decrease in VAS was noted in the IP infusion group with no differences in shoulder pain and additional medication use.

Preemptive analgesia is the approach to blocking neuronal pathways before incision to reduce the hyperexcitability of nociceptors postoperatively. Preemptive analgesia can be achieved by epidural catheters or through local infusion of lidocaine at trocar incision sites prior to incision.

Obese patients with obstructive sleep apnea syndrome (OSAS) appear to be more sensitized to sedation than normal individuals. Mortality may occur in OSAS patients after minimal doses of anesthetics or sedatives due to a change in airway tone resulting in obstruction [23].

The American Society of Anesthesiologists Guidelines for Patients with Obstructive Sleep Apnea Syndrome (OSAS) are intended to improve perioperative care and reduce the risk of adverse outcomes in patients with OSAS who receive sedation, analgesia, or anesthesia. During preoperative evaluation, the severity of the patient's OSAS, the type of surgery and anesthesia, and the requirement for postoperative opioid analgesics should be considered [17].

In summary, after laparoscopic procedures, wound infiltration with local anesthetics and low-dose opioid administration by PCA or oral analgesics can result in acceptable postoperative pain relief.

Question Section

Questions

1. The obese patient is at increased risk for respiratory complications due to:
 - A. Hypoxemia
 - B. Higher respiratory rates
 - C. Lower tidal volumes
 - D. Decreased functional residual capacity
 - E. Obstructive sleep apnea
 - F. All of the above
2. The “sniffing” position of an obese patient during anesthesia induction is preferred to the supine position.
 - A. True
 - B. False

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