An increasing number of bariatric surgeries are performed every year. A thorough understanding of the pathophysiologic changes, surgical procedure, and anesthesia case management for morbidly obese patients and the pharmacology of weight-reduction and anesthetic drugs is essential to provide high-quality anesthetic care. The various comorbidities associated with obesity may complicate anesthetic management. Anesthetists must perform a thorough preoperative assessment to identify potential risk factors related to anesthesia and adequately prepare for intraoperative management. Intubation, maintenance of oxygenation, and pain management may be particularly challenging, and various strategies are presented. In addition, an obese patient is at higher risk for postoperative complications. Signs and symptoms of surgical complications may mimic medical complications, making diagnosis difficult.

Keywords: Bariatric surgery, gastric banding, gastric bypass, metabolic syndrome, obesity.

Objectives
At the completion of this course, the reader should be able to:
1. Describe the pathophysiologic changes that are associated with morbid obesity.
2. Discuss commonly used weight-reduction drugs and the dosing of commonly administered anesthetic drugs given to morbidly obese patients.
3. Compare and contrast the various surgical procedures used for bariatric surgery.
4. List perioperative strategies that can be used to optimize oxygenation/ventilation in morbidly obese patients.
5. Identify the postoperative complications associated with bariatric surgery.

Introduction
Obesity is an epidemic that threatens the health of people all over the world. By estimation of the International Obesity Task Force, more than 1.7 billion people are overweight or obese. Decreased physical activity and overconsumption of high-fat foods are the main contributing factors to the obesity epidemic. Conservative interventions to the treatment of obesity include early education, low-calorie diet, increased physical activity, and, sometimes, medications. However, these treatments are not always effective, and many obese people undergo bariatric surgical procedures. There is a myriad of anesthetic challenges associated with these surgeries. A thorough understanding of the anesthetic considerations is essential to facilitate positive outcomes for the patients.

Pathophysiologic Changes of Obesity
Obesity is commonly associated with a variety of comorbidities, including diabetes, cardiovascular disease, endocrinopathies, and osteoarthritis (Figure 1). The mechanisms underlying these complications are complex and most often are interrelated.
Figure 1. Pathology of Obesity
CVA indicates cerebrovascular accident; DVT, deep venous thrombosis; PE, pulmonary embolism.
The combination of related cardiovascular risk factors, including central obesity, hyperglycemia, hypertension, and dyslipidemia, is referred to as metabolic syndrome. Patients with metabolic syndrome are at higher risk for coronary artery disease (CAD) and experiencing major cardiovascular events. Although each component is recognized as an individual risk factor, the clustering of these risk factors puts a patient at an even greater surgical risk.2

One of the most prevalent disorders associated with obesity is type 2 diabetes resulting from insulin resistance and hyperinsulinemia.1 Hyperinsulinemia frequently results in sodium retention, excessive circulating catecholamines, and increased blood volume.3 Patients commonly have hypertriglyceridemia and low high-density lipoprotein levels, which may contribute to CAD. The American Heart Association reports that obesity may be a major factor for developing heart disease.1 Concentric ventricular hypertrophy, which develops over time, results from increased systemic vascular resistance. The incidence of hypertension increases proportionally as body mass index (BMI) increases.

Fatty changes in the liver may lead to fibrosis and hepatic failure. Nonalcoholic steatohepatitis often occurs in obese children. Cholelithiasis is 6 times more common in people who are obese as in normal-weight people.3 Formation of gallstones also occurs at a higher rate due to the increase in the total body cholesterol level and greater biliary cholesterol excretion.4

Commonly occurring respiratory abnormalities include Pickwickian syndrome, obstructive sleep apnea, decreased functional residual capacity, and increased closing capacity, which all contribute to atelectasis and rapidly occurring hypoxemia.1 These respiratory changes may also lead to polycythemia and cor pulmonale.

Obesity predisposes to osteoarthritis. Increased body weight stresses bones and joints, and this condition is especially common in elderly people. An increased risk of stroke and thromboembolic disease is also prevalent.4

A recent study determined that there may be an association between obesity and various forms of cancer, including esophageal, colon, rectum, liver, prostate, breast, uterus, cervix, and non-Hodgkin lymphoma. Many of these phenomena are hypothesized to be caused by increased estrogen levels.5

### Pharmacology of Obesity-Related Drugs and Anesthetics

- **Antiobesity Medications.** Medications that promote weight loss have limited efficacy. Despite the enormous potential market, efforts to develop effective drug therapies have been disappointing. The US Food and Drug Administration guidance for long-term weight-loss drugs recommends that a 5% weight reduction be maintained for 12 months after treatment initiation. Two drugs are available for use: orlistat (Xenical [prescription form, Roche, Basel, Switzerland]; Alli [over-the-counter form, GlaxoSmithKline, Brentford, England]) and phentermine (Adipex-P [North Wales, Pennsylvania]; others). When used in combination with a comprehensive weight-loss program, they can occasionally be effective in producing weight loss in the range of 4 to 5.5 kg.6

Orlistat is a lipase inhibitor that decreases the absorption of fat in the gastrointestinal tract. It has recently been released as an over-the-counter medication. Side effects are minor and mostly related to gastrointestinal discomfort (Table 1). Phentermine, a sympathomimetic agent, is approved for short-term use (up to 12 weeks) as a weight-management drug. Tolerance, dependence, abuse, and a relatively high number of adverse effects limit its usefulness. Several antidepressant, antiepileptic, and antidiabetic drugs may promote weight loss and are used off-label for this indication.6,7

- **Anesthesia Drugs and Obesity.** Obesity causes physiologic changes that can affect the pharmacokinetics and pharmacodynamics of anesthetic agents. An overview of these changes is given in Table 2. The common approach to anesthetic drug administration is to dose water-soluble drugs according to ideal body weight and lipid-soluble drugs according to total body weight. Lean body mass increases approximately 20% to 40% in obesity, so adding 30% to the ideal body weight is a convenient dose adjustment. Table 3 shows weight calculations commonly used for the dosing of medications.

Contradictory results from individual drug studies in small patient groups are common; therefore, specific recommendations are frequently conflicting. A few general observations can be made. Postoperative respiratory depression is especially problematic in obese patients; therefore, most clinicians favor short-acting drugs that

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**Table 1. Pharmacotherapy for Obesity**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Mechanism</th>
<th>Side or adverse effects</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlistat (Xenical; Alli)</td>
<td>Lipase inhibitor: inhibits intestinal fat absorption by blocking hydrolysis of dietary triglycerides into free fatty acids</td>
<td>Fecal urgency, diarrhea, and abdominal pain; case reports of liver injury under investigation</td>
<td>May interfere with absorption of fat-soluble vitamins A, D, E, and K, requiring supplementation</td>
</tr>
<tr>
<td>Phentermine (Adipex-P; others)</td>
<td>Sympathomimetic agent similar to amphetamines</td>
<td>Primary pulmonary hypertension and many other sympathomimetic adverse effects possible; contraindicated in hypertension and diabetes</td>
<td>Rarely used; only for short-term use; however, has a poor risk-benefit ratio</td>
</tr>
</tbody>
</table>

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allow for fast recovery. The inhalation agents desflurane and sevoflurane produce excellent recovery profiles in obese patients. Although desflurane is less soluble than sevoflurane, clinical differences are minimal. Nitrous oxide can be safely used in patients in whom a requirement for high oxygen concentrations does not preclude its administration. Succinylcholine doses for intubation are given according to total body weight to ensure excellent intubating conditions, whereas the nondepolarizing muscle relaxants used for operative maintenance are given according to ideal body weight. Use of a nerve stimulator to guide relaxant administration assists in minimizing residual paralysis and reversal concerns. Remifentanil infusion is an especially popular analgesic because of the drugs titratability and rapid offset and is administered according to ideal body weight. Dexmedetomidine is also a useful adjunct for sedation, amnesia, and analgesia. Specific dosing recommendations for some common anesthetic agents in obesity are listed in Table 4.

### Surgical Procedure
Because of the epidemic proportions of obesity within the United States, the number of bariatric surgical procedures performed each year has increased. Bariatric surgical programs mandate that before surgery, patients participate in lifestyle modifications to lose weight and learn how to incorporate healthy choices into daily life. It has been demonstrated that preoperative weight loss decreases all of the complications associated after laparoscopic gastric bypass. Psychologists, dieticians, physical therapists, and exercise specialists work with patients

### Table 2. Pathophysiologic Changes in Obesity That May Affect Pharmacokinetics

<table>
<thead>
<tr>
<th>Changes in Pharmacokinetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased fat mass</td>
</tr>
<tr>
<td>Increased cardiac output</td>
</tr>
<tr>
<td>Increased blood volume</td>
</tr>
<tr>
<td>Increased lean body weight</td>
</tr>
<tr>
<td>Changes in plasma protein binding</td>
</tr>
<tr>
<td>Reduced total body water</td>
</tr>
<tr>
<td>Increased renal clearance</td>
</tr>
<tr>
<td>Increased volume of distribution of lipid-soluble drugs</td>
</tr>
</tbody>
</table>

### Table 3. Simplified Weight Calculations

<table>
<thead>
<tr>
<th>BMI</th>
<th>BMI = TBW in kg/height in m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBW in kg</td>
<td></td>
</tr>
<tr>
<td>IBW = height (cm) – 100 for men or 105 for women or</td>
<td></td>
</tr>
<tr>
<td>IBW = 0.8 × TBW for men or 0.75 × TBW for women</td>
<td></td>
</tr>
<tr>
<td>LBW</td>
<td>LBW = IBW × 1.3</td>
</tr>
</tbody>
</table>

### Table 4. Dosing Recommendations for Some Common Anesthetic Drugs in Obesity

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose recommendation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol</td>
<td>Induction dose based on LBW; maintenance dose based on TBW</td>
<td>Increased fat mass does not affect initial distribution/redistribution during induction. Cardiac depression at high doses is a concern.</td>
</tr>
<tr>
<td>Thiopental</td>
<td>Induction dose based on TBW</td>
<td>High cardiac output, volume of distribution, and lean body mass suggest a higher dose requirement. Reduce doses when excess cardiac depression is a concern.</td>
</tr>
<tr>
<td>Succinylcholine</td>
<td>Intubating dose based on TBW</td>
<td>Increased fluid compartment and pseudocholinesterase levels require higher doses to ensure adequate paralysis.</td>
</tr>
<tr>
<td>Rocuronium, vecuronium; cisatracurium</td>
<td>All doses based on IBW</td>
<td>Hydrophilic drugs given according to IBW will ensure shorter duration and a more predictable recovery in this respiratory challenged population.</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>Loading dose based on TBW; maintenance dose based on LBW and response</td>
<td>Increased distribution volume and elimination time correlate with degree of obesity.</td>
</tr>
<tr>
<td>Remifentanil</td>
<td>Infusion rates based on IBW</td>
<td>Distribution volumes and elimination rates are similar to those for normal-sized people. Fast offset requires planning for postoperative analgesia.</td>
</tr>
<tr>
<td>Dexmedetomidine</td>
<td>Infusion rates of 0.2 µg/kg/min</td>
<td>Useful as an adjunct. Lower than usual infusion rates are recommended to minimize adverse cardiac side effects.</td>
</tr>
</tbody>
</table>

TBW indicates total body weight; LBW, lean body weight; and IBW, ideal body weight.
to change their habits and behaviors that contribute to obesity. Furthermore, medical optimization of the patients' coexisting morbidities is essential before surgical intervention.

There are several variations related to the surgical procedures that can be performed. Presently, the most common surgical approach for bariatric surgery is laparoscopy. Furthermore, there is a decrease in the morbidity and mortality associated with laparoscopic gastric bypass with robotic assistance. The goal of bariatric surgery is to reduce the patient's caloric intake by restricting the amount of food that is able to be consumed (gastric restriction procedure) or, by a dual mechanism, to restrict and decrease the amount of absorption from the gastrointestinal tract (mixed restrictive and malabsorptive procedure). Operative mortality (≤ 30 days postoperatively) is estimated to be approximately 0.1% for restrictive procedures and 1% for mixed restrictive and malabsorptive procedures. The most common types of bariatric surgical procedures are laparoscopic adjustable gastric banding and the Roux-en-Y technique.

**Types of Gastric Bypass Procedures**

- **Restrictive Procedures.** Vertical banded gastroplasty is a restrictive procedure that involves the surgical creation of a gastric pouch. The procedure involves making a hole in the middle of the body of the stomach. Stapling of the stomach from the superior aspect of the fundus to the newly created hole is accomplished. The surgeon then fashions a tissue band through the hole that surrounds the remainder of the gastric body near the esophago-gastric junction. Thus, a gastric pouch remains that can accommodate 25 to 30 mL and restricts the amount of food that can be consumed. An illustration of vertical banded gastroplasty is shown in Figure 2A.

  Vertical banded gastroplasty was the most popular surgical intervention for bariatric surgery from the mid 1980s until the early 1990s. Disadvantages to vertical banded gastroplasty include difficulty eating foods that are high in protein, which facilitates the consumption of soft calorie-dense foods, gastroesophageal reflux, and abdominal discomfort. Patients would frequently regain weight, and only 26% were satisfied with the result of the surgery.12

- **Laparoscopic Adjustable Gastric Banding (LAGB)** has become a popular alternative to more invasive malabsorptive surgical procedures and is one of the most common restrictive weight-loss surgeries performed in the United States. This system offers 2 distinct advantages compared with vertical banded gastroplasty: The tension on the band is adjustable, and the system is removable. Laparoscopic adjustable gastric banding is associated with a shorter duration of hospitalization, decreased pulmonary complications, and overall decreased morbidity and mortality compared with other bariatric surgical options.13 There are several adjustable bands, including Lap Band (Alleran Inc, Irvine, California), Realize Adjustable Gastric Band (Ethicon Endo-Surgery Inc, Cincinnati, Ohio), and the Swedish adjustable gastric band. The gastric band is placed immediately distal to the gastroesophageal junction. An illustration of the LAGB is shown in Figure 2B. Contained within the silicone band,
A balloon is inflated to decrease the size of the proximal aspect of the stomach. The balloon is inflated with saline via an access port that is positioned subcutaneously. The pouch that is created holds approximately 100 to 200 g of food. Distention of the pouch causes satiety resulting from afferent sensory and visceral neural innervation.

Identification of patients who are ideal candidates for LAGB improves the postoperative percentage of weight loss. Increased age, increasing BMI, hyperinsulinemia, type 2 diabetes, and polycystic ovarian syndrome are associated with a lower percentage of weight lost after surgical intervention. It has been demonstrated that weight loss with LAGB frequently results in complete resolution or improvement of type 2 diabetes, hypertension, and dyslipidemia. The indications and contraindications for having LAGB are included in Table 5.

Numerous potential complications are associated with LAGB surgery. An analysis of 7 years' of data from 2,909 patients related to the safety of the LAGB includes the following complications and frequencies: band slippage, 4.5%; port-related problems, 3.3%; and reoperation for weight gain, 0.4%. One or more of these complications were experienced by 12.2% of patients. The overall incidence of erosion of the stomach under the gastric band is 1.96%. Postoperative mortality within 30 days or fewer is approximately 0.06% to 0.1%. A rare complication called Barrett esophagus can occur after LAGB. Barrett esophagus occurs due to chronic gastroesophageal reflux, which causes esophageal erosion and predisposes patients to malignant changes. The overall incidence is unknown; however, cellular dysplasia and esophageal adenocarcinoma that is related to gastroesophageal reflux disease can occur after gastric banding. A comprehensive list of complications associated with LAGB are included in Table 6.

**Indications**
- Body mass index ≥ 40 kg/m²
- Failure to lose weight with dietary restrictions and pharmacologic therapy for > 1 y
- Obesity for > 5 y
- Understanding of the surgical and anesthetic risks and benefits
- Willingness to adhere to lifelong dietary restrictions
- Acceptable operative risk
- Comorbid diseases that improve with weight loss (eg, diabetes, metabolic syndrome, cardiovascular disease)

**Contraindications**
- Unreasonable surgical risk
- Untreated hypothyroidism
- Gastrointestinal inflammatory disease (eg, ulcers, Crohn disease, ulcerative colitis)
- Severe cardiopulmonary disease
- Pain intolerance to implantable devices
- Alcohol and/or drug addiction
- Severe cognitive disabilities
- Allergy to silicone

**Table 5. Indications and Contraindications to Laparoscopic Adjustable Gastric Banding**
(Adapted from Dixon and O’Brien)

**Adjustable gastric band**
- Gastric mucosal erosion around the band
- Gastritis
- Erosion of gastric mucosa under the band, causing perforation
- Filling port malfunction
- Gastric prolapse
- Malposition of the band
- Barrett esophagus
- Dysphagia
- Gastroesophageal reflux

**Malabsorptive procedures**
- Bowel obstruction
- Wound dehiscence
- Leakage and/or ulcers at the sites of anastomosis
- Nutritional deficiency
- Incisional hernia
- Gastrojejunojostomy stenosis

**Potential complications of both types of procedures**
- Hemorrhage
- Dumping syndrome (more common in gastric bypass)
- Postoperative respiratory insufficiency
- Deep vein thromboembolism
- Pulmonary embolism
- Sepsis

**Sleeve Gastrectomy** is accomplished by decreasing the size of the stomach to approximately 20% of its original size by removing a substantial portion of the stomach. This procedure is most frequently performed laparoscopically and involves resection of a substantial portion of the gastric fundus and body to create a tubelike opening from the gastroesophageal junction to the pyloric valve. The reconstructed stomach ideally will have a total gastric volume of between 100 and 200 mL. This procedure is shown in Figure 2C. In general, patients lose between 30% and 50% of excess body weight within 1 year.

**Combined Restrictive and Malabsorptive Procedures.** Roux-en-Y gastric bypass (RYGB) is the most common combined restrictive and malabsorptive form of gastric bypass surgery in the United States. The National Institutes of Health has determined that the most ef-

**Table 6. Complications Associated With Bariatric Surgery**
(Adapted from Matarasso et al)

- Band slippage
- Port-related problems
- Reoperation for weight gain
- Barrett esophagus
- Dysphagia
- Gastroesophageal reflux
- Bowel obstruction
- Wound dehiscence
- Leakage and/or ulcers at the sites of anastomosis
- Nutritional deficiency
- Incisional hernia
- Gastrojejunojostomy stenosis
- Hemorrhage
- Dumping syndrome (more common in gastric bypass)
- Postoperative respiratory insufficiency
- Deep vein thromboembolism
- Pulmonary embolism
- Sepsis
Effective surgical treatment for obesity is RYGB. The procedure is frequently accomplished via a laparoscopic approach with or without robotic assistance, and there are a number of variations of this technique. A small gastric pouch (15-20 mL) is constructed from the cardia portion of the stomach near the gastroesophageal junction and restricts the amount of food that the patient can eat at one time. The pouch is attached to the distal duodenum and becomes the “Roux limb” or “alimentary limb,” where food and fluids travel and are absorbed. The biliopancreatic limb is formed proximally from the duodenum, and the distal resected end is anastomosed to the ileum to form a common small intestinal limb. This procedure is illustrated in Figure 3A.

A polypeptide called ghrelin is primarily secreted by the stomach and small intestine. When secreted, this hormone stimulates appetite. Since removal of various portions of the stomach and duodenum occurs as part of malabsorptive procedures for obesity, another mechanism of weight loss is associated with decreased plasma ghrelin levels. It has been demonstrated that ghrelin values are up to 47% lower in patients who have undergone the RYGB procedure compared with equally obese nonsurgical patients.

There has been substantial interest in which bariatric surgical procedure is most effective, LAGB or RYGB. The major advantage of the LAGB is that it is reversible; however, the percentage of excess body weight loss is less variable and consistently greater with the RYGB. Reversal of comorbidities is greatest after LAGB. Perioperative complications were more likely to occur during RYGB than during LAGB, but long-term reoperation rates were lower and patient satisfaction was higher with the RYGB gastric bypass procedure. Adams and colleagues determined that the long-term mortality after RYGB is decreased from any cause and from diseases specifically attributed to obesity. A list of bariatric surgical procedures and the percentage of excess body weight lost within the first year is listed in Table 7.

Because of the intricacy associated with this procedure, complications such as leaks from the distal and proximal sites of anastomosis, bowel obstruction, vitamin deficiency, and intestinal stenosis can occur. Dumping syndrome occurs in approximately 10% of patients who undergo any type of gastric bypass surgery. It occurs when food from the stomach is rapidly transported or “dumped” into the duodenum. The severity of the abdominal cramping and nausea associated with this phenomenon varies from mild to severe. This side effect is more common after gastric bypass compared with LAGB. Treatment includes medications such as acarbose (Precose, Bayer Corp, West Haven, Connecticut) or surgical reintervention. A comprehensive list of complications associated with malabsorptive bariatric surgical procedures is listed in Table 6.

- Biliopancreatic Diversion With Duodenal Switch includes a hemigastrectomy or sleeve gastrectomy to create a 75- to 100-mL pouch. The ileum is connected directly...
to the gastric pouch, completely bypassing the duodenum and jejunum (alimentary limb). The distal portion of the biliopancreatic limb is then reconnected 100 cm from the ileocecal valve. Thus, in addition to being restrictive due to the gastric sleeve, the now substantially shorter small intestine offers less intestinal surface area for absorption to occur. A representation of this procedure is shown in Figure 3B.

Biliopancreatic diversion with duodenal switch is most often performed for patients who are described as superobese (BMI ≥ 55 kg/m²). Prachand and colleagues determined that excess body weight loss of more than 50% was achieved in 83.9% of patients having biliopancreatic diversion with duodenal switch and 70.4% with Roux-en-Y 1 year postoperatively.

The development of gallstones commonly occurs after gastric bypass procedures, and some surgeons perform a cholecystectomy simultaneously. Inadequate absorption of proteins, iron, calcium, and fat-soluble vitamins (A, D, E, and K) can occur, and multivitamin supplementation is recommended.

A new procedure under investigation to determine the safety and efficacy in treating obesity is an implantable gastric stimulator. A pulse generator the size of a cardiac pacemaker is implanted on the surface of the stomach. The afferent impulses that are sensed by the brain allow the person to feel satiated. In the future, as new surgical techniques, technological advances, and the discovery of new medications occur, the treatment of obesity will become safer and more effective.

### Table 7. Percentage of Excess Body Weight Lost by Type of Bariatric Surgery Within the First Year

(Adapted from Maggard et al.21)

<table>
<thead>
<tr>
<th>Type of Bariatric Surgery</th>
<th>Percentage of Excess Body Weight Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustable gastric banding</td>
<td>25%-80%</td>
</tr>
<tr>
<td>Sleeve gastrectomy</td>
<td>65%-75%</td>
</tr>
<tr>
<td>Vertical gastric banding</td>
<td>50%-60%</td>
</tr>
<tr>
<td>Roux-en-Y gastric bypass</td>
<td>50%-70%</td>
</tr>
<tr>
<td>Biliopancreatic diversion with duodenal switch</td>
<td>65%-75%</td>
</tr>
</tbody>
</table>

### Anesthetic Management

#### Preoperative Evaluation
Preoperative evaluation of a bariatric surgical patient should include an evaluation by a multidisciplinary team and focus on the identification, treatment, and optimization of modifiable health concerns. Many bariatric surgical candidates have already been diagnosed and medically managed for comorbid conditions by their primary care physicians; therefore, the additional need to perform extensive diagnostic tests is minimal. A candid discussion between the surgeon and patient regarding realistic expectations, lifestyle alterations, diet modifications, and exercise is necessary. Common criteria for bariatric surgery include the following: a BMI of 40 kg/m² or more or of 35 kg/m² or more with comorbid conditions, failure of nonoperative weight-loss efforts, absence of contraindications, and a well-informed, compliant, and motivated patient with a good support system. Absolute contraindications for bariatric surgery include a lack of understanding of the procedural risks, severe liver disease with accompanying portal hypertension, uncontrolled severe obstructive sleep apnea with pulmonary hypertension, and unstable or terminal illness.

A thorough history and physical examination, vital signs, baseline laboratory studies, and informed consent should be obtained during the initial assessment, and, if needed, referral to and consultation with appropriate subspecialties should be accomplished. Risk identification and risk reduction should be priorities that can assist in the identification of appropriate surgical candidates. The Obesity Surgery–Mortality Risk Score has been designed and validated to predict the risk of mortality in patients undergoing bariatric surgery. One point is assigned to each of 5 preoperative variables:

1. BMI 50 kg/m² or more
2. Male gender
3. Hypertension
4. Risk for pulmonary embolism (history of venous thromboembolism, pulmonary hypertension, and/or obesity hypoventilation)
5. Older than 45 years

A score of 0 or 1 is classified as “A” or lowest risk, 2 or 3 as “B” or intermediate risk, and 4 or 5 as “C” or high risk, with mortality ranging from 0.2% for an A classification, to 1.3% for a B classification, to 2.4% for a C classification.

A primary goal of the preoperative assessment is treatment and optimization of comorbid conditions. Obese patients frequently have comorbid conditions such as hypertension, CAD, diabetes, venous thromboembolism, and/or obstructive sleep apnea. Patients referred to cardiology for suspicion of CAD should undergo an exercise or dobutamine stress echocardiogram to evaluate cardiac function. Bariatric surgery can be safely performed on patients with known CAD without major increases in perioperative mortality and cardiac complications, provided the patients have been thoroughly evaluated and appropriately managed.

Patients suspected of having obstructive sleep apnea should undergo polysomnography and receive treatment preoperatively and throughout the perioperative period. Treatment modalities include continuous positive airway pressure, noninvasive positive-pressure ventilation, and bilevel positive airway pressure. Pulmonary function should be evaluated to anticipate the need for postoperative controlled ventilation.

Patients at risk for postoperative venous thromboembolism (venous stasis disease, BMI ≥ 60 kg/m², truncal
obesity, prior venous thromboembolism, and known hypercoagulable states) may be considered for placement of an inferior vena cava filter before bariatric surgery. Although expert consensus concerning dosing guidelines does not exist, prophylactic anticoagulation is commonly ordered by most bariatric surgeons.25 Heparin, 5,000 IU, is administered subcutaneously before surgery and then every 12 hours in combination with the use of pneumatic compression devices. Early ambulation is also suggested for effective thromboprophylaxis.29 Some surgeons prefer the administration of low-molecular-weight heparin such as enoxaparin.

Preoperative endoscopy is not routinely performed and is reserved for patients with symptomatic reflux, dyspepsia, or dysphagia. As mentioned earlier, lipid deposition in hepatocytes may induce liver damage and cause simple fatty infiltration or cirrhosis. The terms nonalcoholic fatty liver disease and nonalcoholic steatohepatitis are used to describe inflammatory changes that occur in the liver with or without fibrosis. Some bariatric surgeons routinely perform liver biopsies during bariatric procedures to diagnose and stage nonalcoholic fatty liver disease/nonalcoholic steatohepatitis.24

It is suggested that each bariatric surgical candidate undergo an electrocardiogram and chest radiograph testing to further investigate cardiopulmonary risk.24,25 In patients with diabetes, the serum glucose level should be maintained at less than 150 mg/dL. A hemoglobin A1c value of less than 7% is desirable to reduce surgical risk.24 Commonly recommended laboratory tests are listed in Table 8.

With the exception of insulin and oral hypoglycemic agents, patients should continue their usual medication regimen.29 Antibiotic therapy is instituted to decrease the risk of postoperative wound infection. Medications for anxiolysis, analgesia, and aspiration and venous thromboembolism prophylaxis are commonly administered preoperatively. Aspiration prophylaxis medications include histamine-2 blockers, antacids, and metoclopramide.

A thorough airway examination should be completed to identify the possibility of a difficult airway. There is controversy regarding whether obesity is a predictor of difficult endotracheal intubation. Mallampati scores of 3 or greater, neck circumferences greater than 43 cm at the thyroid cartilage, a decreased thyromental distance, and a high BMI are all predictors of potential difficult endotracheal intubation.30 Invasive monitoring using arterial and central venous pressures should be considered in patients with poor cardiopulmonary function. In addition, a central venous catheter should be considered in obese patients in whom venous access is challenging or as otherwise indicated from the patient’s health history.

- **Intraoperative Anesthetic Management.** Morbidly obese (MO) patients present many challenges during the intraoperative period. Major areas of concern include airway management, maintenance of oxygenation, patient positioning, and monitoring.

General endotracheal anesthesia is the technique of choice for laparoscopic bariatric surgery. Rapid-sequence induction with cricoid pressure remains important to avoid gastric aspiration in obese patients with symptomatic gastroesophageal reflux or other predisposing conditions such as diabetes mellitus and gastrointestinal disorders.31 However, the necessity of rapid-sequence induction with cricoid pressure because of a presumed risk of aspiration in an obese, fasting patient with no other risk factors is controversial.32

A prudent approach to a known or highly suspected difficult airway would be an awake, fiberoptic intubation. If tracheal intubation with direct laryngoscopy is planned, appropriate positioning, preoxygenation, and preparation of emergency airway equipment is essential. Traditional teaching has emphasized the supine sniffing position to aid in airway instrumentation. In MO patients, multiple studies have demonstrated that creating a blanket ramp or reconfiguring the operating table to a 30° back-up position provides optimal conditions for successful intubation.29,33 In these studies, aligning the external auditory meatus with the sternum horizontally has been shown to improve the laryngoscopic view (Figure 4). If airway management and intubation prove difficult, emergency airway adjuncts, including a gum elastic bougie, laryngeal mask airway, video laryngoscope, or fiberoptic endoscope, may be used.

Because of alterations in pulmonary function, such as reduced functional residual capacity and oxygen reserves, MO patients are likely to experience rapid oxygen desaturation during the induction of general anesthesia, and increased atelectasis may develop throughout the case (Figure 5). Maximizing the oxygen content in the lungs before tracheal intubation is important to decrease these risks. The application of continuous positive airway pressure during preoxygenation, induction with the patient in a head-up position, along with the addition of positive end-expiratory pressure (PEEP) and mechanical ventilation by mask after induction have been shown to prevent atelectasis and desaturation.34,35

Safe intraoperative ventilation of MO patients poses a substantial challenge to anesthesia providers. This chal-

Table 8. **Suggested Preoperative Laboratory Testing**

<table>
<thead>
<tr>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete blood cell count</td>
</tr>
<tr>
<td>Comprehensive metabolic panel</td>
</tr>
<tr>
<td>Liver function tests</td>
</tr>
<tr>
<td>Glucose/hemoglobin A1c</td>
</tr>
<tr>
<td>Prothrombin time/partial thromboplastin time</td>
</tr>
<tr>
<td>Lipid profile</td>
</tr>
</tbody>
</table>
The challenge is especially important when considering the negative pulmonary effects of the pneumoperitoneum during bariatric surgery. Complete muscle relaxation is crucial during these procedures to facilitate ventilation and prevent collapse of the pneumoperitoneum. Numerous strategies to maintain intraoperative oxygenation and lung volumes in MO patients have been recommended. The use of high tidal volumes, alveolar recruitment maneuvers, positive end-expiratory pressure, and high oxygen concentrations have been studied extensively, and none are conclusively superior. Increasing tidal volumes more than 13 mL/kg in MO patients has been found to increase peak inspiratory pressures and end-expiratory airway pressures but does not substantially improve arterial oxygen tension. When compared with the supine position, the use of a 30° reverse Trendelenburg position during bariatric surgery reduces the alveolar-to-arterial oxygen difference, increases total ventilatory compliance, and reduces peak airway pressures. Alveolar recruitment by repeated sustained lung inflation to 50 cm/H₂O followed by the addition of 12 cm/H₂O of positive end-expiratory pressure during mechanical ventila-

Figure 4. Optimal Body Position for Successful Intubation of Morbidly Obese Patients

Figure 5. Oxygen Desaturation in Morbidly Obese Patients
tion can increase intraoperative PaO\textsubscript{2} but may result in hypotension that requires vasopressor support. Mechanical ventilation using pressure-controlled instead of volume-controlled ventilation results in improved oxygenation in MO patients. Table 9 summarizes various strategies for intraoperative ventilatory management while protecting against ventilator-induced lung injury.

Safe positioning of obese patients may require a specially designed operating table or 2 regular tables joined together. Standard-size operating tables have a maximum weight limit of approximately 200 kg, but operating tables with a weight maximum of 455 kg are available. Pressure sores, neural injuries, and rhabdomyolysis are more common in MO patients and patients with diabetes. Special care should be given to positioning and padding pressure points before and throughout the surgical process because changes in operating table position or surgical manipulation may cause body shifts.

As with all patients, invasive arterial monitoring may be considered for obese patients with concomitant cardiopulmonary disease. The conical shape of the upper arm may present difficulties in obtaining an accurate noninvasive blood pressure reading, and invasive monitoring may be deemed necessary. To avoid inaccurate readings, appropriate cuff size includes a bladder that encircles a minimum of 75% of the upper arm circumference or the entire arm. Comparable and accurate blood pressure readings can be obtained from the wrist or ankle with appropriately sized cuffs.

Delayed recovery from anesthesia may occur due to sequestration of lipid-soluble anesthetic drugs in MO patients. Special consideration should be taken to ensure the patient has fully recovered protective airway reflexes, adequate respirations, and complete muscle strength before extubation. In addition, placing the patient in the reverse Trendelenburg position improves alveolar recruitment and distention, decreases atelectasis, and may help to improve oxygenation throughout emergence.

- **Postoperative Management.** Pathophysiologic changes in obese patients, along with coexisting diseases, affect
not only the intraoperative management but also the postoperative management. Early identification of complications is essential. Postoperative complications in MO bariatric surgical patients are derived from pathophysiologic changes due to obesity, coexisting diseases, and the surgical procedure.

The pulmonary changes in obese patients, such as increased chest wall resistance, decreased functional residual capacity, and forced vital capacity, along with the effects of intraoperative mechanical ventilation result in a substantial incidence of postoperative atelectasis and hypoxemia. Therefore, optimizing oxygen administration by placing the patient in the head-up position increases functional residual capacity and decreases the work of breathing.

Patients who have obstructive sleep apnea are at increased postoperative risk for respiratory failure.\textsuperscript{40,41} ASA practice guidelines suggest that patients receiving continuous positive airway pressure or bilevel positive airway pressure preoperatively should receive it immediately postoperatively.\textsuperscript{41} These ventilatory support modalities prevent alveolar collapse during expiration and allow alveolar recruitment during inspiration.\textsuperscript{40,42} They also act to displace the tongue and soft tissues, thereby preventing airway obstruction. Concerns that continuous positive airway pressure may cause gastric insufflation and distention resulting in anastomotic failure have largely been discredited.\textsuperscript{43}

The surgical approach for bariatric surgery also contributes to postoperative pulmonary complications. Open abdominal approaches reduce functional residual capacity and forced expiratory volume in 1 second more than laparoscopic approaches. In addition, they are also associated with more postoperative pain than laparoscopic approaches, resulting in tachypnea, shallow breathing, and impairment of respiratory mechanics.\textsuperscript{42} Regardless of the surgical approach, inadequate postoperative pain management can lead to hypoxemia, hypercarbia, and atelectasis.\textsuperscript{44}

Management of postoperative pain in MO patients is challenging. Morbidly obese patients have exaggerated respiratory depression from opioids. A multimodal approach to postoperative pain may be superior. However, in patients with obstructive sleep apnea, the respiratory depressant effects are more pronounced; therefore, opioid-sparing techniques help avoid respiratory complications.\textsuperscript{41}

Multimodal approaches to postoperative pain management include intravenous opioid administration based on ideal body weight, local anesthetics injected into the wound or port site, neuraxial anesthesia, and the use of nonsteroidal anti-inflammatory agents.\textsuperscript{45,46} Investigations have shown that an infusion of dexmedetomidine decreases postoperative opioid requirements.\textsuperscript{8,45,46} Another current pain management alternative is the continuous intraperitoneal infusion of bupivacaine.\textsuperscript{47}

### Table 10. Signs and Symptoms of Anastomotic Leak

Anastomotic leak is the most common cause of surgically related mortality in bariatric patients.\textsuperscript{48,49} Signs and symptoms of an anastomotic leak are listed in Table 10. These symptoms are often subtle and nonspecific, making early diagnosis difficult.\textsuperscript{49}

Other physiologic changes associated with morbid obesity, such as greater blood volume, polycythemia, sedentary lifestyle, and venous stasis, increase the risk of deep venous thrombosis and pulmonary embolism. Consequently, pulmonary embolism is the second most common cause of mortality related to bariatric surgery.\textsuperscript{44,48}

Postoperative signs and symptoms of pulmonary embolism include tachypnea, tachycardia, chest pain, hypoxemia, arrhythmias, and a feeling of “doom.”\textsuperscript{43} Differential diagnosis of pulmonary embolism may be challenging because many of these symptoms mimic a bowel leak.\textsuperscript{48}

The anesthetic management for bariatric surgery presents many challenges. These include managing comorbid conditions, airway management, oxygenation, fluid and medication calculation, and postoperative pain management. A thorough understanding of the pathophysiologic changes, pharmacology of weight-loss drugs and anesthetic agents, and perioperative course will allow a high-quality, safe surgical experience.

### REFERENCES


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