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Thoracic Anesthesia for Morbidly Obese Patients and Obese Patients with Obstructive Sleep Apnea

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Key Points

- A patient with a BMI >30 kg/m^2 is considered obese. A patient with a BMI >40 kg/m^2 is morbidly obese (also known as Obesity Class III). Super-obesity refers to a patient with a BMI >50 kg/m^2.
- Morbid obesity (MO) is associated with medical conditions, including hypertension, type II diabetes mellitus, cardiovascular disease, obstructive sleep apnea (OSA), and obesity hypoventilation syndrome (OHS).
- Moderate to severe OSA is present in more than 50% of MO patients and is often unrecognized. The best screening tool for identifying patients with OSA is the STOP-Bang questionnaire. In the absence of a definitive diagnosis by polysomnography (PSG), all MO patients should be managed as if they have OSA.
- Anesthesiologists should have a high index of suspicion for the presence of OHS. Patients with OHS have a greater risk of cardiovascular problems and pulmonary hypertension.
- Preoperatively, treatment with continuous positive airway pressure (CPAP) can significantly improve OSA symptoms. The patient should bring their CPAP equipment to the hospital for use during their postoperative recovery.
- Many MO patients are difficult to ventilate by mask, but tracheal intubation by direct laryngoscopy is usually successful.
- The best preoperative predictors of potential problems with tracheal intubation in MO patients are high Mallampati (III or IV) score and increased neck circumference (>48 cm men, >40 cm women).
- A supine obese patient should not be allowed to breathe without assistance. All MO patients should be positioned in the “head-elevated laryngoscopy position” (HELP) prior to induction of anesthesia.
- Depressant medications should be avoided preoperatively as they can decrease ventilatory responsiveness to hypoxemia and hypercarbia and can cause airway collapse in the presence of OSA.
- Regional anesthesia techniques should be used when possible, including epidural or paravertebral analgesia for thoracic procedures.
- Obese patients are not at increased risk for gastric aspiration, and therefore rapid sequence induction is usually unnecessary.
- MO patients tolerate one-lung ventilation (OLV) in the lateral position but are unlikely to tolerate it in the supine position.
- For MO patients lean body weight (LBW) should be calculated for dosing of induction and opioid agents, IBW for non-depolarizing neuromuscular agents, and TBW for succinylcholine.
- MO patients can develop rhabdomyolysis (RML) after long-duration procedures. Any associated myoglobinuria can lead to acute renal failure. RML is treated by aggressive IV fluid administration.

Introduction

Advances in airway techniques, new drugs, and equipment have enabled anesthesiologists to manage even the most complex thoracic surgical patient. One group of patients,

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Table 33.1 Modified World Health Organization body mass index (BMI) classification

BMI (kg/m^2)	Classification
Below 18.5	Underweight
18.5–24.9	Normal weight (Ideal body weight)
25.0–29.9	Pre-obesity (overweight)
30.0–34.9	Obesity Class I (obese)
35.0–39.9	Obesity Class II (obese)
Above 40	Obesity Class III (morbid obesity)

those with morbid obesity (MO), can be especially challenging. Throughout the world, obesity levels over the past two decades have reached epidemic levels [1]. Extremely obese patients now routinely present to the operating for surgery [2]. MO patients differ from their normal-weight counterparts due to alterations in their anatomy and physiology [3]. They often have significant comorbid medical conditions that can complicate their operative course and increase the risks of postoperative problems. Obstructive sleep apnea (OSA), which is very common in obesity, further contributes to the complexity of managing these patients.

Obesity is usually described by body mass index (BMI). BMI is calculated by dividing patient weight in kilograms (kg) by the square of their height in meters (m), expressed as BMI = kg/m^2. BMI is an indirect estimation of obesity since it considers any increase in weight, not just increases in adipose tissue. Obesity definitions have changed over the years. The current BMI categories are listed in Table 33.1 [4]. Based on these definitions, more than one third of American adults are obese (BMI >30 kg/m^2), and almost 5% are MO (BMI >40 kg/m^2) [5]. The population with extreme weight has been increasing fastest [6, 7], and a new BMI category termed super-obesity is now used to describe larger patients (BMI >50 kg/m^2).

This chapter will describe the perioperative anesthetic considerations for the obese thoracic surgical patient. To date a limited number of reviews on this topic have been published [2, 8]. Most recommendations for obese patients undergoing thoracic surgery are derived from studies of patients undergoing other types of surgery, particularly weight loss operations.

Preoperative Considerations

A thorough preoperative assessment is indicated for every surgical patient. For the MO patient, the anesthesiologist must consider the associated comorbid conditions associated with extreme obesity (including hypertension and cardiovascular disease, type II diabetes, OSA and OHS, osteoarthritis), in addition to the medical indication for surgery. The specific preoperative management of each of these medical comorbidities is beyond the scope of this chapter, and the reader is referred to reviews on the subject [3, 9, 10].

Weight

Preoperative documentation of the MO patient's height and weight is extremely important for optimal pharmacologic management. Anesthetic drugs are usually administered by patient weight, either total body weight (TBW), ideal body weight (IBW), or lean body weight (LBW). Clinical trials during drug development usually have not included obese and MO subjects, so drug dosing in these patients based solely on actual or TBW can lead to overdosing, complicating perioperative management.

IBW is a measure initially derived by life insurance companies in the 1940s to describe the weight for a man or woman of a specific height that was statistically associated with maximum life expectancy. Accepted values for IBW have increased over the past seven decades since patients are now living longer despite significant increases in their average weight. In normal-weight patients TBW approximates IBW, that is, "normal" weight ranges between ± 10% of IBW. For drug dosing IBW can be estimated for both men and women using the formula, IBW = 22 × (height in meters)^2 [11].

LBW includes the weight of muscles, bones, tendons, ligaments, and body water. It is equal to actual weight (TBW) minus the weight of fat. LBW in nonobese patients should be about 80% TBW for males and 75% TBW for females. LBW and TBW both increase as a patient gets heavier since there are increases in the muscle and body water in addition to the much larger increases in adipose tissue. LBW can account for as much as 20–40% of the excess TBW [12, 13]. LBW is difficult to measure clinically, but it can be calculated by several formulas. Most formulas for LBW fail when applied to the extremely obese population. Equations 33.1 and 33.2 [14] are used to accurately estimate LBW (Fat Free Mass) in obesity:

$$T_o = \frac{Q_o}{D} = \frac{6000}{400{,}000} = 0.015\,\text{years} = 5.475\,\text{days} \tag{33.1}$$

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For clinical anesthetic drug dosing, LBW can be roughly estimated in a MO patient simply by their IBW + 20–30%.

Pulmonary Function

Excess body fat significantly reduces chest wall and total pulmonary compliance. Airway resistance and work of breathing are increased in the spontaneously breathing MO patient. Preoperatively, spirometry usually reveals a restrictive defect with decreases in functional residual capacity (FRC), mainly expiratory reserve volume (ERV), associated with small airway collapse during tidal breathing. These changes result in ventilation/perfusion (V/Q) mismatch, an elevated shunt fraction, and relative hypoxemia [15].

Preoperative pulmonary function testing has been used to predict which patients can safely tolerate lung resection [16, 17]. The minimum values of at least 40% FEV_1 and 40% diffusion capacity may not be useful in the MO patient since these measurements are not indexed to weight. No predictive baseline spirometry studies for MO patients undergoing lung resection are available. However, as BMI increases, postoperative FEV_1 and FVC values decrease proportionally [18]. For example, following abdominal surgery MO patients experience significantly more atelectasis, greater decreases in FRC, and lower P_aO_2 values than matched normal-weight patients. Therefore, it is very likely, but still unproven, that MO patients also experience greater reductions in pulmonary function following thoracic operations than nonobese patients.

Obstructive Sleep Apnea

OSA is characterized by repetitive collapse of the upper airway during sleep, which results in complete cessation (apnea) or near complete cessation (hypopnea) of airflow. Apnea is defined as a total lack of airflow lasting at least 10 s. Hypopnea is a decrease of ≥50% in airflow or ≤50% decrease for at least 10 s. These events are associated with either arousal from sleep or oxygen desaturation of ≥ 3% [19]. If there is increasing respiratory effort, the apnea is described as "obstructive," whereas in central sleep apnea, there is no breathing effort. Besides snoring, frequent awakenings, and apnea periods during sleep, OSA patients often have a history of daytime drowsiness, morning headaches, irritability, personality changes, depression, cognitive impairment, and visual incoordination. Severe OSA is associated with sleep fragmentation, transient hypoxemia and hypercapnia, large negative intrathoracic pressure swings, and marked elevations in blood pressure [20].

OSA is formally diagnosed by a "sleep study" (polysomnography, PSG). The apnea index (AI) is the number of apneas/hour of total sleep time. The hypopnea index (HI) is the number of hypopneas/hour of total sleep time. The sum of the AI and HI is the apnea-hypopnea index (AHI) [19]. The arousal index (ARI) is the number arousals/hour of total sleep that do not meet the definitions of apneas or hypopneas. The combination of ARI and AHI is the respiratory disturbance index (RDI), a measure that significantly correlates with excessive daytime sleepiness. An AHI >5 in combination with clinical symptoms is diagnostic of OSA.

The prevalence of moderate to severe OSA (apnea-hypopnea index (AHI) ≥15 events/hour) in the general population is 10–20% [21] and as high as 70% in MO patients undergoing bariatric surgery [22]. Another study quotes the rate of OSA in MO patients to be 84% (AHI >5), 47% (AHI >15), and 27% (AHI >30) [23]. There have been many screening tools proposed for identifying OSA. The STOP and STOP-Bang questionnaires [24] are currently used in anesthetic practice. The STOP questionnaire includes four questions related to snoring, tiredness, observed apnea, and high blood pressure. The STOP-Bang questionnaire has four additional demographic questions: BMI, age, neck circumference, and male gender. The published sensitivity and specificity of the STOP and STOP-Bang questionnaires are given in Table 33.2. The probability of OSA being present increases as the STOP-Bang score increases. The ease of use and high level of sensitivity have resulted in the questionnaire being widely used as screening tool in preoperative clinics and is especially useful if a PSG is not obtained.

Table 33.2 STOP and STOP-Bang questionnaires sensitivity and specificity in surgical patients

	STOP questionnaire		STOP-Bang questionnaire	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
OSA (AHI >5)	65.6	60	84	56.4
OSA (AHI >15)	74	53	93	43
OSA (AHI >30)	80	49	100	37

Adapted from Chung et al. [24]

Patients with OSA also have metabolic changes. Intermittent hypercapnia secondary to nocturnal and even daytime obstructive apnea or hypoventilation may lead to elevation in serum bicarbonate levels as a compensatory mechanism for acute respiratory acidosis. Bicarbonate elevation correlates with AHI, and when used in conjunction with the STOP-Bang score, the specificity of the presence of moderate to severe OSA significantly increases [25].

Identifying patients who have OSA has important perioperative implications. Intermittent nocturnal sympathetic activation from hypoxemia and hypercarbia causes systemic hypertension. Recurrent hypoxic pulmonary vasoconstriction eventually results in pulmonary hypertension and right and left ventricular hypertrophy. OSA patients may have a higher rate of complications, including difficult intubation, difficult bag-mask ventilation, cardiopulmonary complications, unexpected reintubation, and ICU admission [26–28].

Continuous positive airway pressure (CPAP) is used to treat moderate to severe OSA. CPAP provides a pneumatic stent that opens the upper airway and maintains its patency. For patients requiring high levels of CPAP or those with chronic obstructive pulmonary disease as occurs in many thoracic surgical patients, bi-level positive airway pressure (BIPAP) is used since it allows for independent adjustment of inspiratory and expiratory positive airway pressure unlike the fixed single setting for CPAP [29]. OSA patients scheduled for an elective procedure can experience significant improvement in their symptoms if they are begun on CPAP therapy preoperatively. Tongue volume decreases, and pharyngeal space enlarges following several weeks of CPAP, potentially simplifying airway management. Preoperative use of CPAP also improves other medical comorbidities including congestive heart failure, hypertension, and perhaps even pulmonary hypertension.

Since OSA is so common in the MO population, all patients should be presumed to have OSA and be managed within that context. The American Society of Anesthesiologists (ASA) consensus guideline document for the perioperative management of patients with OSA [30] and a recent review by Corso et al. [31] are useful resources for planning the perioperative management of any MO patient undergoing thoracic surgery.

Obesity Hypoventilation Syndrome

OHS patients present with the same symptoms as OSA patients but usually have lower daytime oxygen saturations and more severe pulmonary hypertension. OHS is defined by daytime hypercapnia and hypoxemia (P_aCO_2 >45 mm Hg and P_aO_2 <70 mm Hg) in an obese patient (BMI >30 kg/m^2) who has sleep-disordered breathing in the absence of any other cause of hypoventilation [32]. In its severest form, OHS has been termed “Pickwickian syndrome.” In OHS there is a diminished central ventilatory drive despite elevated P_aCO_2. Although OHS is rare in the general population, the incidence is estimated to be between 5% and 10% in MO OSA patients, with the highest occurrence in super-obese patients.

Compared with eucapnic MO patients with sleep-disordered breathing, patients with OHS have higher risk of developing serious cardiovascular disease. Electrocardiographic evidence of right heart strain and hypertrophy is common. A preoperative arterial blood gas sample, preferably with the patient breathing room air, should be obtained. It will establish a baseline and document the degree of P_aCO_2 elevation and the presence of elevated bicarbonate levels. Polycythemia is usually present secondary to chronic hypoxemia, and this further increases an already elevated risk for postoperative pulmonary embolism. Given that the prevalence of extreme obesity in the surgical population has increased considerably, it is likely that clinicians will encounter patients with OHS who are scheduled for thoracotomy. Therefore, maintaining a high index of suspicion can lead to early recognition and treatment reducing the high morbidity and mortality associated with undiagnosed and untreated OHS.

Cardiovascular Function

Absolute blood volume and cardiac output are increased in obesity. The presence of OSA further increases the risks of pulmonary and systemic hypertension. These factors eventually lead to “eccentric” right ventricular hypertrophy, left ventricular hypertrophy, and development of right and left heart failure (“obesity cardiomyopathy”) in older MO patients [33]. A routine electrocardiogram is usually adequate for most MO patients, even those with arterial hypertension. However, even in asymptomatic obese patients, some degree of right ventricular dysfunction can be demonstrated by echocardiography. The presence of angina or other cardiac symptoms requires a more thorough cardiac evaluation. In one small study, moderate or severe left ventricular diastolic dysfunction was present in 50% of patients with moderate or severe OSA, while there was no disease in patients with no or mild OSA [34]. Long-standing or severe OSA should alert one to the possibility of pulmonary hypertension and right ventricular failure and prompt preoperative echocardiographic evaluation.

Premedication

Centrally depressant medications can decrease ventilatory responsiveness to hypoxemia and hypercarbia in any obese patient, but in the MO patient with OSA, these drugs also decrease pharyngeal dilator muscle tone and activity causing upper airway collapse. Many anesthetic agents and medications are associated with pharyngeal collapse, including opioids, benzodiazepines, nitrous oxide, thiopental, propofol, and even small doses of neuromuscular blocking agents. Sedatives given preoperatively can have prolonged effects in any MO patient, and when OSA is present they increase the risk of respiratory depression even into the postoperative period. For MO thoracic surgical patients, sedative premedication should be used with caution or preferably avoided completely.

Intraoperative Management

Induction Dosing of Anesthetic Agents

Anesthetic medications should always be dosed according to a per kilogram dosing regimen. It is important to measure the TBW of a MO patient and calculate IBW and LBW. The extra weight in MO patients is made up of both adipose and lean tissue, with adipose increasing at a higher proportion. Because fat has lower blood flow than lean tissue, the plasma concentration of an IV injected drug in a MO patient would rise significantly if the dose was based on TBW.

A dosing regimen that is specific to the physiologic changes present in morbid obesity should be used. Most induction agents and opioids are administered based on LBW. IBW is used to dose non-depolarizing neuromuscular blockers, and TBW is used for succinylcholine [35]. An induction dose of propofol based on TBW would predictably have increased cardiovascular side effects such as hypotension and myocardial depression [36]. LBW is a more accurate dosing scalar in MO subjects for propofol induction.

Patient Position

Unlike normal-weight patients, an awake, spontaneously breathing MO patient should never be allowed to lie flat prior to induction of anesthesia. In the supine position, MO patients experience a further reduction in their already reduced FRC. This can result in dangerous hypoxemia, especially if they are breathing air. Obese patients preoxygenated in sitting position have significantly extended tolerance to apnea after muscle paralysis (longer "safe apnea time," SAT) when compared with similar obese patients preoxygenated in the conventional supine position [37]. Also, in the supine position any decreased venous return from compression of the inferior vena cava by increased abdominal pressure can cause hypotension.

MO patients should always be positioned prior to anesthetic induction so that their upper body and head are elevated to a point that their sternum and ear are aligned in a horizontal line (otherwise referred to as "head-elevated laryngoscopy position" or HELP) [38]. Figure 33.1 In addition, if the patient is hemodynamically stable, the operating room table should be in the reverse Trendelenburg position (RTP) [39]. The Semi-Fowler's position with the patient's upper body elevated 25–30° also extends SAT [40], but the 30° RTP is better [41]. In these head-up and upper body elevated positions, the patient's panniculus drops down and "unloads" the diaphragm, which in turn increases FRC. The combination of the patient in the HELP with the operating room table in the RTP maximizes FRC and also improves the view during direct laryngoscopy.

The head-up position in obese patients, without adequate arm support, can result in brachial plexus injury [42]. Changing to the lateral position for thoracotomy or thoracoscopy requires additional physical assistance and equipment. Axillary rolls should be proportionally larger to protect the brachial plexus. Beanbags to support the patient in the lateral decubitus position may not sufficiently wrap around the patient due to their excessive girth, and patients may need to be restrained with belts or tape across the pelvis. Supporting the head in the lateral, flexed position can be difficult due to a proportionally short neck and requires creative placement of towels and blankets to ensure that the head is positioned on a horizontal line extending through the spine of the patient, in a neutral position (Fig. 33.2).

Airway

The patient's previous anesthesia records should be reviewed for documentation of any prior difficulties with tracheal intubation. A MO patient, especially one with a history or symptoms suggestive of OSA, may have a diminution of the

Fig. 33.1 Prior to induction of general anesthesia, the morbidly obese patient should never be allowed to lie flat but should be positioned in the head-elevated laryngoscopy position (HELP). In this position, an imaginary horizontal line can be drawn from their sternum to their ear. HELP improves the view during direct laryngoscopy and increases safe-apnea time after muscle paralysis. If the patient is hemodynamically stable, the operating table should be in 30° reverse Trendelenburg to further increase safe-apnea time

Fig. 33.2 After turning the patient to the lateral decubitus flexed position, supporting the patient's head can be difficult due to a proportionally short neck in many MO patients. Creative placement of towels and blankets is required to ensure that the head is positioned on a horizontal line extending through the spine of the patient, in a neutral position

pharyngeal space secondary to fat deposition in the pharyngeal wall, which can make airway access and bag-mask ventilation difficult. The patient's airway and anatomy should be closely examined. Airway management of MO patient has been reviewed elsewhere [43, 44].

The American Society of Anesthesiologists Task Force defines a difficult airway as the "clinical situation in which a conventionally trained anesthesiologist experiences problems with (a) face mask ventilation of the upper airway or (b) tracheal intubation or both" [45].

The criteria used to define difficult mask ventilation usually include failure to maintain oxygen saturation (SpO_2) >92%, the need for two providers, and/or complete inability to mask ventilate. Increased BMI and a history of OSA are each independent predictors for difficult mask ventilation [46], and there is general acceptance that MO patients, especially when supine, are more difficult to ventilate by mask than normal-weight patients. Age 49 years, short neck, and neck circumference are additional factors that have been identified as independent predictive factors for difficult bag-mask ventilation [47].

Numerous studies have considered tracheal intubation in the MO population. The view obtained during direct laryngoscopy is usually used as a measure for difficult or failed intubation; however, an ETT may be easy to place despite a poor laryngoscopic view, and even with a reasonable view there can be difficulty passing a tube. In MO patients video-laryngoscopy improves intubation conditions [48] and reduces hypoxic events during induction [49]. The best preoperative predictors of potential problems with tracheal intubation are Mallampati score (III/IV) and increased neck circumference [50].

The standard sniffing position for tracheal intubation is achieved in nonobese patients by raising their occiput 8–10 cm with a pillow or headrest. Obese patients require much greater elevation of their head, neck, and shoulders (HELP) to produce the same alignment of axes for intubation [38]. In studies of MO patients where the head position is suboptimal, which is not in the HELP, there are higher incidences of grade 3 and 4 Cormack-Lehane views potentially increasing difficulty with direct laryngoscopy [51]. Video-laryngoscopy for routine tracheal intubation has presumably led to better visualization of the glottis in MO patients [52]. In patients who are anesthetized and in whom a difficult laryngoscopy is encountered, an alternative method to securing the airway could involve passing a single-lumen endotracheal tube (ETT) through a laryngeal mask with the aid of a flexible fiberoptic bronchoscope [53, 54].

Certain clinical features are more likely to be present in obese or MO patients in whom direct laryngoscopy is difficult. As mentioned, high Mallampati score, large neck circumference, and excessive pretracheal adipose tissue may make laryngoscopy more difficult in some MO patients [50, 55]. However, increasing weight alone has never been correlated with increasing difficulty with tracheal intubation. BMI has no direct influence on difficult laryngoscopy, and rates of successful tracheal intubation in these MO patients are similar to those in nonobese patients [50, 56, 57]. In a small subset of male, MO patients with short wide necks, OSA, and high Mallampati scores direct laryngoscopy may be more difficult, and video-laryngoscopy should be considered for these patients. Anesthesiologists should always proceed with caution in any MO patient since difficulty with bag-mask ventilation is very common and all obese patients have a short SAT following muscle paralysis for laryngoscopy.

For most MO patients, an IV anesthetic induction with propofol and succinylcholine is the best means for securing the airway. Rocuronium can be used, but only if sugammadex is immediately available. Formally, a rapid sequence induction (RSI) was believed to be necessary for all MO patients because of the misperception that obesity increased risk for aspiration and pulmonary injury during anesthetic induction. It is now felt that most MO patients are at no greater risk than normal-weight patients. Obese patients that are at higher risk for gastric acid aspiration are those with a history of severe GERD and diabetic gastroparesis and patients who have previously undergone gastric banding procedures [58]. For these patients a RSI is still recommended. RSI is not without risks (awareness, under- and overdosing of drugs, impaired visualization during laryngoscopy, SpO_2 desaturation), and these risks are potentially greater than the low risk of aspiration.

In summary, for MO obese patients, induction of anesthesia and tracheal intubation should include placing the patient in a head-up position, adequate preoxygenation until end-tidal oxygen concentration is >80%, administration of fast-acting opioids to supplement the anesthetic induction agent, titration of the induction agent until loss of consciousness is achieved, avoidance of cricoid pressure (if possible), and continued bag-mask positive pressure ventilation following the administration of a neuromuscular blocking agent until the patient is fully paralyzed and ready for tracheal intubation. Bag-mask ventilation can be difficult and gastric insufflation from ineffective mask ventilation can increase the risk of regurgitation and acid aspiration. A second person experienced with airway management, preferably another anesthesiologist, should always be readily available to assist when difficulty is encountered.

Lung Separation

Safe and dependable isolation and selective ventilation of the lungs are essential for the practice of modern thoracic anesthesia. Lung separation is accomplished with either a DLT or with a balloon-tipped BB. There is no “best” method for lung separation, and choice of technique depends on the specific surgical requirements, the patient’s airway, and the individual anesthesiologist’s preferences and experience [59]. Despite the technical aspects of placing any airway device, it has also been shown that one of the most significant barriers to successful lung separation is the operator’s knowledge of bronchial anatomy [60, 61]. Bronchoscopic tracheobronchial anatomy can be reviewed using an online simulator at www.thoracicanesthesia.com or www.pie.med.utoronto.ca/VB or in published illustrations [61].

Direct laryngoscopy and successful placement of a DLT or ETT should be no different in obese and normal-weight patients, provided the obese patient is appropriately positioned for laryngoscopy. In both normal-weight patients [62] and obese patients [63], tracheal intubation is usually more difficult using a DLT than with a single-lumen tube.

When problematic laryngoscopy is anticipated, or if difficulty is experienced when attempting to place a DLT, an ETT can be inserted using either a gum elastic bougie as a guide, through any of several laryngeal mask airways (LMAs) using fiberoptic bronchoscopy, or with any other intubation adjunct such as a Trachlight® [53, 54]. Once the ETT is in place, a BB can be used through the ETT, or alternatively a 100-cm long airway exchange catheter can be employed to change from the ETT to a DLT. A DLT can even be placed directly by fiberoptic bronchoscopy [64].

When tube exchange is not practical, lung isolation can always be achieved with a BB through the ETT. BB may be a better choice for those MO patients with high Mallampati score and thick necks with a potential “difficult” airway. The quality of lung collapse is unaffected whether a BB or DLT is used [59]. If postoperative ventilation is planned, it may be safer to avoid a DLT entirely and use a BB through an ETT since changing tubes at the completion of surgery can be potentially dangerous in MO patients.

Prior to intubation the patient’s chest radiograph or CT scan should be examined to determine the tracheobronchial anatomy and airway diameters [65]. Unlike chronic obstructive lung disease, which results in a dilation of trachea and bronchi, a similar effect does not occur for the restrictive lung disease associated with obesity. Relatively, small tracheas are often found in very large patients. Even if a smaller DLT needs to be used, airway resistance is not a concern. Contrary to popular belief, most sizes of DLTs have reduced airflow resistance compared to ETTs [66].

One-Lung Ventilation

Hypoxemia during OLV is significantly affected by patient positioning. Normal-weight patients undergoing OLV in the supine position have significantly lower arterial oxygen tensions than when the same patient is in lateral position [67]. For patients undergoing thoracotomy in the supine, the semilateral decubitus, and the lateral decubitus positions, oxygenation progressively decreases with time after the start of OLV. OLV in the supine position is associated with the highest incidence of hypoxemia, usually occurring approximately 10 min after initiating OLV with 100% oxygen [68]. Although MO patients maintain adequate oxygenation during OLV in the lateral position, they are much less likely to tolerate OLV in the supine position. Basilar atelectasis is present in supine MO patients preoperatively and worsens following induction of general anesthesia. MO patients benefit from lung recruitment maneuvers following induction of anesthesia, particularly prior to the institution of OLV [69]. Due to the presence of more atelectasis in dependent lung areas than normal-weight patients, recruitment maneuvers and PEEP are required for maintaining adequate oxygenation [70, 71]. Despite this, arterial oxygen tension in MO patients remains significantly lower during OLV than normal-weight patients [72]. Successful OLV in MO patients is technically possible in the lateral position if the panniculus can fall away from the body, therefore unloading the dependent diaphragm (Fig. 33.3).

For all patients, including the MO patients, lung protective ventilation strategies are practiced during OLV [73, 74]. Traditional ventilation parameters (large tidal volume with no recruitment or PEEP) may contribute to the development of ARDS and other postoperative pulmonary complications [75–77], even in patients without preexisting lung disease [78, 79]. Ventilation with tidal volumes as high as 13 mL/kg (IBW) during OLV do not improve oxygenation and can

Fig. 33.3 Successful one-lung ventilation (OLV) in MO patients is technically possible in the lateral position if the panniculus can fall away from the body unloading the dependent diaphragm. MO patients are much less likely to tolerate OLV in the supine position since many patients already have reduced FRC and are relatively hypoxemic even during two-lung ventilation when they lie flat

result in excessively high peak pressures [80]. In the MO population, estimating tidal volumes based on actual weight (TBW) or height is a risk factor for delivering excessively high tidal volumes during mechanical ventilation [81, 82]. As with normal-weight patients, tidal volumes during OLV should be based on IBW (4–6 mL/kg IBW).

High peak inspiratory pressures secondary to restriction of chest wall and diaphragmatic excursion and the narrow single lumen of a DLT can further limit volume-controlled mechanical ventilation during OLV. Pressure-controlled ventilation during OLV can improve oxygenation and decrease peak pressures in normal-weight patients [83]. Pressure-limited OLV may have an application in the MO population, but if too low tidal volume is delivered to a patient with an already low FRC, hypoxemia will worsen. PEEP is beneficial during two-lung ventilation in MO patients. During OLV, a mild to moderate level of PEEP to the single ventilated dependent lung has been shown to improve oxygenation if it does not exceed the lower inflection point of the alveolar pressure-volume loop. High PEEP results in increased pulmonary vascular resistance thereby increasing shunt fraction and worsening hypoxemia [84].

Anesthetic Drugs/Maintenance of Anesthesia

MO patients should be managed as if they have OSA. When practical, opioid-sparing anesthetic techniques, including regional anesthesia, should be used. Short-acting anesthetic and analgesic agents are appropriate choices for the MO patient. All opioids have respiratory depressant properties, and IV administration should be carefully titrated according to individual patient needs. Remifentanil is administered based on LBW in MO patients.

Some anesthesiologists prefer a total intravenous anesthesia (TIVA) technique with propofol and remifentanil, while most find an inhalational technique combined with epidural analgesia best for thoracotomy. In a study of 120 MO patients [85], neither technique was associated with intraoperative awareness.

In current anesthetic practice, propofol is the induction agent of choice for surgical patients, including MO patients. In theory, a lipid-soluble agent like propofol should be dosed according to TBW, but if this was followed in MO patients, such large doses could result in cardiovascular collapse, particularly in the fluid restricted thoracotomy patient. For MO patients, the induction dose of propofol is based on LBW [36].

Succinylcholine should be used for tracheal intubation in the MO patient. The concentration of pseudocholinesterase, the enzyme that metabolizes succinylcholine, increases with increasing weight. A 1 mg/kg TBW dose of succinylcholine provides a rapid and profound neuromuscular block and better intubating conditions than non-depolarizing muscle blockers. Rocuronium can be used, but only if sugammadex is available. Non-depolarizing muscle relaxants are initially dosed based on LBW, and a neuromuscular monitor is used to guide additional dosing.

When considering volatile anesthetics, isoflurane is more lipophilic than desflurane or sevoflurane, making it more soluble in adipose tissue. Desflurane and sevoflurane have each been marketed as anesthetics for MO patients. However, in obese patients, fat is poorly perfused and comparable recovery times with both agents have been reported in obese and nonobese subjects after anesthetic procedures lasting 2–4 h. There are no clinical differences in emergence and recovery profiles in MO patients receiving either desflurane or sevoflurane when anesthetic concentration is carefully titrated [86]. However, a meta-analysis review on the topic found that patients given desflurane took less time to emerge from anesthesia; that is, they took less time to respond to commands to open their eyes, to squeeze the investigator's hand, to be prepared for tracheal extubation, and to state their name. There were no differences in hemodynamics and respiratory function perioperatively using either agent [87]. There were no significant differences in postanesthesia care unit discharge times, nausea, or analgesic requirement [88]. Despite claims to the contrary, there is no clear advantage between any of the inhalational anesthetics in MO patients [89].

Intravenous Fluid Management

Routine clinical practice is to restrict IV fluid to reduce the incidence of postoperative pulmonary edema after lung resection [90]. Therefore, perioperative assessment of blood volume (BV) is particularly critical for patients undergoing thoracotomy. The mean value for BV in normal-weight adults is usually given as 70 mL/kg, but this value cannot be used for obese and MO patients. With progressive increase in BMI, total circulating BV also increases, but BV measured as mL/kg TBW decreases in a nonlinear manner [91]. Using 70 mL/kg will overestimate BV in MO patients and can lead to under-administration of crystalloids, colloids, and red blood cells in the event of massive fluid translocation and/or hemorrhage.

Emergence and Extubation

Early extubation of the trachea at the completion of pulmonary resection lowers the risk of bronchial stump disruption and pulmonary air leaks secondary to positive pressure ventilation and airway tube trauma. In normal patients, a DLT can be removed while the patient is still in the lateral position, followed by assisted mask ventilation until the patient is fully awake. In the MO patient, especially one with OSA, mask ventilation in the lateral position can be difficult. Tracheal extubation in a MO patient should be performed with the patient in HELP and the operating room table in the RTP to optimize ventilation and to allow access to the airway if reintubation becomes necessary.

A MO patient must be sufficiently awake and have a regular respiratory pattern before the trachea is extubated. Although it is rarely necessary, a DLT can be replaced with an ETT via an airway exchange catheter, and the patient can then be allowed to emerge from anesthesia. Alternatively, after deflating both the tracheal and bronchial cuffs and withdrawing the tube until the endobronchial segment is in the trachea, the tracheal cuff can be reinflated and the DLT used as a single-lumen tube. A DLT completely in the trachea is less stimulating than one still in the bronchus. Even when a DLT remains in the bronchus, it is tolerated by patients, and most anesthesiologists elect to keep the DLT in place. The tube is removed after routine criteria for extubation have been met.

It has been suggested that noninvasive positive pressure ventilation (NIPPV) be employed to reduce post-extubation complications. A Cochrane Database review demonstrated that there was no additional benefit of using NIPPV in postoperative pulmonary resection [92]. Outcomes such as pulmonary complications, rate of reintubation, mortality, rate of non-pulmonary complications, postoperative consumption of antibiotics, length of intensive care unit stay, length of hospital stay, and adverse effects related to NIPPV were analyzed. Based on low to moderate quality evidence, the authors concluded that more studies were needed to establish this conclusion with greater certainty.

Despite these findings, for the MO patient who has been using CPAP or BIPAP preoperatively, these devices should be available and used immediately after tracheal extubation to stent the upper airway, to reduce the work of breathing, and to improve tidal volume and gas exchange [22]. The noninvasive Boussignac mask-CPAP (BCPAP) system does not require a mechanical ventilator and is very helpful in maintaining satisfactory oxygenation in spontaneously breathing MO surgical patients [93, 94]. Supplemental oxygen should always be administered, but used with caution as oxygen therapy can increase the AHI, hypoventilation, and P_aCO_2 levels in a patient with OHS. Continuous, noninvasive, transcutaneous carbon dioxide ($P_{tc}CO_2$) monitoring is accurate and has been applied to MO patients, especially those with OSA and OHS to evaluate abnormalities in their alveolar ventilation [95].

Postoperative Pain Control

Satisfactory post-thoracotomy analgesia is extremely important to maximize lung function, particularly in the MO patient who has restricted lung function prior to surgery.

Epidural opioid analgesia, with or without local anesthetic, when compared to IV opioids reduces pain, improves pulmonary function and oxygenation and reduces post-thoracotomy complications [96]. Local anesthetics given epidurally also supplement general anesthesia and reduce opioid requirements during surgery. Postoperative pain control for thoracotomy is covered in detail elsewhere in this book.

In the postoperative period, it is known that lung volumes are significantly reduced. Lung volumes in obese patients are probably reduced even further. Although the effects of thoracic epidural analgesia (TEA) compared to conventional opioid-based analgesia in postoperative spirometry has not been studied in obese patients undergoing thoracotomy, it has in laparotomy patients [18]. Perioperative spirometry values decreased significantly with increasing BMI, with the greatest reduction in vital capacity immediately after tracheal extubation. The effects were less in all patients receiving TEA, but in obese patients (BMI >30 kg/m2), the difference in vital capacity was significantly more pronounced than in normal patients. Recovery of spirometry values was significantly quicker in patients receiving TEA, particularly in the obese patients.

With epidural analgesia, any postoperative hypotension and/or motor blockade from the local anesthetic will limit the MO patient's ability to ambulate increasing their already greater risk for pulmonary embolism. A Cochrane review revealed that continuous thoracic paravertebral (PVB) analgesia is as effective as epidural analgesia in managing post-thoracotomy incisional pain [97] and is associated with a lower incidence of complications, including fewer pulmonary complications, less nausea and vomiting, less hypotension, and fewer failed blocks than epidural analgesia [98]. Unlike epidural analgesia, paravertebral analgesia only blocks the operative side and ipsilateral parasympathetic chain. In some studies, the stress response to surgery with PVB is reduced more than what is achieved by epidural analgesia [99]. As evidence for the effectiveness of PVB grows, some predict that it will likely replace epidural analgesia as the preferred method of post-thoracotomy pain control [100, 101].

Early institution of postoperative multimodal analgesic regimens that can include local anesthetics, interpleural local anesthetic infusions, nonsteroidal anti-inflammatory agents, and other synergistic drugs to reduce the respiratory depressant effects of centrally acting agents is indicated for MO patients with OSA. Alpha-2 agonists (clonidine, dexmedetomidine) do not depress respiration and have analgesic properties and have been used as adjuncts to epidural local anesthetics for post-thoracotomy analgesia [102].

Complications

Studies have reported that extremely obese patients undergoing cardiac surgical procedures have longer recovery times and a greater incidence of postoperative complications and mortality than normal-weight patients [103]. Although the same may be true for MO patients undergoing thoracotomy, there have been few outcome studies to corroborate this. Most published post-thoracotomy outcome studies have considered obese (BMI >30 kg/m^2) and not MO or super-obese patients [104]. One recent study did find a weak correlation between obesity (BMI >30 kg/m^2) and increased length of hospital stay after thoracic surgery [105]. It is interesting to note that there was a much higher association of complications in low BMI (<18.5 kg/m^2) patients following thoracotomy. Many other large series of patients undergoing non-thoracic operations have reported similar results, that is, obesity (BMI >30 kg/m^2) is not a major risk factor but low BMI (<18.5 kg/m^2) is highly associated with surgical complications and death [70]. This association has been referred to as the "obesity paradox" [106].

The risk of postoperative thromboembolism, atelectasis, and pneumonia is believed to be greater in MO surgical patients undergoing non-thoracic operations [107]. Presumably, the same is true for similar size patients undergoing thoracic surgery, but once again, no studies are available that can document this concern.

There is one postoperative complication that is now recognized as relatively common in MO surgical patients but rare in normal-weight patients. Rhabdomyolysis (RML) results from pressure injury to skeletal muscle due to prolonged stasis in a non-physiologic position, such as the lateral decubitus position [108]. Long-duration surgery is the major risk factor, but other factors include super-obesity, male patients, and a history of hypertension, diabetes and/or peripheral vascular disease. Intraoperative padding of all pressure points and close attention to patient positioning are essential to prevent RML, pressure ulcers, and neurologic damage in MO patients. Injured muscle releases myoglobin, electrolytes, and protein into the systemic circulation. Myoglobinuria can lead to acute renal failure (ARF), and electrolyte disturbances can cause dysrhythmias and even cardiac arrest. Local signs and symptoms of RML are nonspecific and include pain, tenderness, swelling, bruising, and weakness. Complaints of numbness and muscular pain are almost always present, but epidural analgesia can mask symptoms and delay diagnosis.

Myoglobinuria usually presents as "tea" or brown-colored urine. The primary diagnostic indicator of RML is elevated serum creatine phosphokinase (CPK) levels. A MO patient who complains of buttock, hip, or shoulder pain in the postoperative period and who has a serum CPK level >1,000 IU/L is considered to have RML. Treatment should be instituted once CPK levels increase beyond 5,000 IU/L. Although intraoperative fluid replacement can reduce the risk of postoperative RML, fluid replacement is usually restricted during pulmonary resections. However, once a diagnosis of RML is made, aggressive hydration with large volumes of intravenous fluids and administration of diuretics are required to flush myoglobin from the kidneys.

Surgical Issues

Operative exposure in a MO patient may be less than optimal as the usual lateral decubitus position with extreme table flexion may not result in an adequate opening of the chest wall. Exposure is further compromised by increased chest wall thickness. Soft-tissue thickness also becomes important during video-assisted thoracoscopy (VATS) procedures since longer instruments are needed and range of motion may be limited. Unsatisfactory conditions for VATS can lead to more frequent conversion to thoracotomy, but once again, it is unclear as to whether this complication occurs more often in MO patients. The possibility of changing from VATS to open thoracotomy has important implications since it raises issues as to whether an epidural catheter should be placed preoperatively in a "technically difficult" VATS patient when there is a high likelihood of proceeding to thoracotomy. If the surgeon can place paravertebral catheters for postoperative pain control, the concern for unnecessary epidural placement is alleviated.

Conclusion

MO patients comprise an ever-increasing percentage of the thoracic surgical population. Obesity is not a contraindication to thoracic surgery; however, given the potential problems of extreme obesity, thorough perioperative planning is critical to prevent problems. There is a paucity of published studies involving MO thoracic surgical patients, so current anesthetic management is based on experience from obese patients undergoing non-thoracic surgical procedures. Research to further refine specific anesthetic management strategies for MO thoracic surgery patients is needed.

Clinical Case Discussion

Case A 56-year-old, 180 cm, 148 kg (BMI 46 kg/m^2) man with lung cancer is scheduled for a right-upper lobectomy. He is active and reports no limitations to his ability to work in the construction industry. His medical problems include mild hypertension and type-2 diabetes mellitus. He has never been hospitalized and has no history of previous surgery. During his preoperative examination, his wife says that he snores loudly at night. He has never had a formal sleep study (polysomnography, PSG). On examination, he has a grade III Mallampati airway with a neck circumference of 50 cm. The patient and his surgeon want to proceed with his surgery as soon as possible.

Preoperative Management

What further studies are needed?

- Although spirometry may be useful, it is doubtful that it would demonstrate an inability for this patient to tolerate the surgery since he is active and has no respiratory impairment. Pulmonary function studies in MO patients demonstrate a reduction in lung volume (mainly FRC) and a restrictive breathing pattern.

Should the patient undergo a preoperative PSG study?

- Given the patient's BMI (46 kg/m^2) and history of snoring, it is more likely than not that he has obstructive sleep apnea (OSA). The patient is positive for 6/8 questions on his STOP-Bang assessment (snoring, hypertension, BMI, age, neck circumference, and male). Although a PSG test would confirm the diagnosis, even without testing this patient (and most MO patients) should be treated as if they have OSA.

Should the surgery be postponed while the patient is placed on CPAP?

- This patient is anxious to proceed with the surgery immediately. Several weeks of preoperative CPAP therapy might be helpful, but surgery will be delayed. Many patients do not tolerate CPAP, and he may refuse to wear the device.

In addition to a routine ECG, does his cardiac status require further evaluation?

- A stress echocardiogram would be informative given his age and comorbidities, but it is not essential since he has a high exercise tolerance and is active. The majority of MO surgical patients do not need an extensive preoperative cardiac workup.

What needs to be done prior to induction of anesthesia?

- In the preoperative area, unless the patient is extremely anxious, sedation should be avoided. Midazolam, 1-2 mg IV, can be given, but no opioid premedication.
- Since a thoracotomy is planned, a thoracic epidural (TEA) should be placed for intra- and postoperative analgesia. A continuous paravertebral block (PVB) is alternative with the advantage being it would have a better postoperative profile (less hypotension and absence of motor blockade) than a TEA. It is important that all perioperative opioids, including postoperative PCA opioids, be kept to a minimum in this MO patient with OSA.
- An arterial line should be placed to obtain a baseline blood gas and for intra- and postoperative monitoring.
- On arrival in the operating room, he should not be allowed to lie flat since this will lead to further reductions in his FRC and decrease in safe apnea time (SAT). He should be positioned on the operating table with his upper body elevated by pillows and blankets in the "head-elevated laryngoscopy position" (HELP).

Intraoperative Management

How should the patient's airway be intubated?

- A potentially difficult intubation is always possible, especially since his preoperative assessment demonstrated a high Mallampati score and large neck circumference. The choice of proceeding with a conventional IV anesthetic induction and direct laryngoscopy, video-laryngoscopy, or even an "awake" fiberoptic intubation is up to the confidence and experience of the anesthesiologist. With the availability of video-laryngoscopes, fiberoptic bronchoscopy for intubation (which often requires sedation) is seldom required. Video-laryngoscopes can be used to intubate the trachea with a double-lumen tube (DLT) or with an endotracheal tube (ETT). However, a second trained physician or nurse should always be immediately available to assist with bag-mask ventilation (which is frequently difficult in MO patients) and/or with airway intubation.
- The patient should be preoxygenated with 100% oxygen until his end-tidal oxygen is >80%. A true "rapid sequence induction" is not needed since this patient has no risk factors for aspiration. The patient should be ventilated by mask once rendered apneic to increase his SAT until laryngoscopy is initiated.
- If an IV induction is chosen, we prefer propofol and succinylcholine. Rocuronium can be used, but only if sugammadex is available. Succinylcholine provides better relaxation for tracheal intubation.
- If with direct laryngoscopy the patient has a favorable Cormack-Lehane grade view, a left DLT could be placed and checked with flexible bronchoscopy.
- For more difficult views, a gum elastic bougie could be inserted through the glottis, followed by an ETT over the bougie. If intubation by direct or video-laryngoscopy and a bougie is not possible, an LMA could be placed, and a fiberoptic bronchoscope could then be used to intubate the trachea. Once the airway is secured, lung separation can then be accomplished with either a bronchial blocker through the ETT, or the ETT can be replaced with a DLT using a long airway exchange catheter (AEC).

Is there a better technique for one-lung ventilation – total IV anesthesia (TIVA) or inhalation technique?

- Although TIVA has theoretic advantages (less depression of hypoxic vasoconstrictive reflex), clinically there is no difference in oxygenation during one-lung ventilation using either technique.
- Long acting opioids should be avoided during surgery with either technique.
- Lung size does not increase with obesity. Tidal volume during volume-controlled OLV should be based on ideal body weight (4–6 mL/kg IBW) and not actual weight. Plateau pressure during pressure-controlled ventilation should not exceed 30 cm H_2O.
- CPAP to the non-ventilated lung is useful to maintain oxygenation. PEEP to the ventilated lung should also be used.

Postoperative Management

What if the patient complains of pain, even with a functioning TEA or PVB?

- Supplemental IV opioid analgesia should be kept to a minimum; multimodal analgesic techniques should be used both intra- and postoperatively.

How do you manage postoperative oliguria?

- The differential diagnosis includes hypovolemia from the routine practice of fluid restriction during thoracotomy and/or rhabdomyolysis, which is relatively frequent in MO patients. In either case, additional IV fluid administration is indicated.
- A serum CPK level should be obtained to rule out renal failure secondary to rhabdomyolysis. Clinically significant rhabdomyolysis results in myoglobinuria. This usually doesn't occur unless the CPK level is >5,000 IU/L, but aggressive fluid therapy should be instituted if the CPK level is >1,000 IU/L, a level diagnostic of RML.

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