The patient with obesity and super-super obesity: Perioperative anesthetic considerations

ABSTRACT
Obesity is associated with increased morbidity and mortality related to many complex physiologic changes and the rise worldwide has had far ranging implications in healthcare. According to the World Health Organization, over 2.8 million people die each year from being overweight or obese. Patients who are obese often need surgical procedures or interventional pain procedures and are at higher risk of complications. Patients with super-super obesity are those with body mass index greater than 60 kg/m² and are at even greater risk for complications. The present investigation reviews epidemiology, pathophysiology, and anesthesia considerations for best practice strategies in managing these higher risk patients. Clinical anesthesiologists must utilize careful assessment and consultation in developing safe anesthesia plans. Improvements in technology have advanced safety with regard to airway management with advanced airway devices and in regional anesthesia with ultrasound-guided nerve blocks that can provide increased flexibility in formulating a safe anesthetic plan. As well, newer drugs and monitors have been developed for perioperative use to enhance safety in patients with obesity.

Key words: Anesthesia, morbid obesity, obstructive sleep apnea, super-super obesity

Introduction

Obesity is growing at an alarming rate worldwide. After a nearly 40% rise in prevalence from 2000 to 2018, 42.2% of adults in the United States are obese. Similar statistics worldwide reflect an epidemic rise in all age groups. In this regard, the rate of obesity is over one in six in the age range of 2 and 19 years, which has more than tripled in the past 20 years. The prevalence of severe obesity has also nearly doubled from 4.7% to 9.2% during this time. obesity can be measured through body mass index (BMI), which evaluates the relationship between weight in kilograms and height in meters squared. The World Health Organization defines adult obesity as a BMI ≥30 kg/m². However, recent spikes in the disease have prompted additional classifications, including severe obesity as a BMI ≥40 kg/m², super obesity as a BMI ≥50 kg/m², and super-super obesity as a BMI ≥60 kg/m².

Comorbidities are extensive and affect nearly all organ systems with a higher risk of high blood pressure, diabetes

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mellitus, heart disease, joint and bone problems, sleep apnea, decreased self-esteem, decreased mobility, shortened life span, and higher incidence of nerve injury under sedation. These comorbidities inevitably add to a higher rate of peri-operative mortality. Therefore, these patients require careful pre-operative assessment and intra-operative management by anesthesiologists. A primary anesthetic concern in pre-operative assessment is the patient’s airway. Obesity is the leading risk factor of obstructive sleep apnea (OSA) by causing upper airway collapse and resulting in apneic episodes during sleep. Patients with obesity have considerably greater oxygen consumption related to the metabolic activity of fat, which can result in exceeding greater than three times oxygen consumption when compared with normal-sized people. Increased energy expenditure in breathing is also related to increased chest and abdominal wall mass. Excess adipose tissue around the neck, pharynx, and mouth contributes to airway obstruction, increasing the incidence of OSA and making mask ventilation and intubation potentially much more difficult. Combined with quicker oxygen desaturation times, airway maintenance can especially be challenging for these patients.

Cardiovascular changes related to obesity include higher rates of hypertension, ischemic heart disease, left ventricular hypertrophy, and congestive heart failure. Gastrointestinal changes related to obesity include higher risk of aspiration related to reduced gastric emptying and diabetes, all having some degree of gastroparesis when compared with nonobese patients. Fatty infiltration of the liver can influence pharmacokinetics of sedation medications. The volume of distribution is increased because of hypervolemia and increased cardiac output in patients with obesity. Elimination of medications can be reduced by a variety of factors in patients with obesity. In this regard, sedation delivered to patients with obesity is associated with increased morbidity and mortality.

Obesity also presents unique intra-operative risks complicated by generally longer operative times, thus more time under general anesthesia. One controversial intra-operative issue is the appropriate dosing of anesthetics. With changes in cardiac output and blood volume, many parameters guiding drug dosages, such as drug clearance and volume of distribution, differ from those of normal BMI. The choice of anesthetic also changes in patients with obesity due to many agents lingering in excessive reserves of adipose tissue. Longer washout times frequently result in these patients taking longer to awake. Although the specific anesthetic choice is debated, a guiding principle should favor short-acting and minimal fat-soluble sedatives due to a higher prevalence of OSA and higher sensitivity to respiratory depressants. After rolling out of the operating room, the management of these patients remains challenging. The mainstay of post-operative pain, opioids, should be carefully monitored due to a higher risk of significant respiratory depression. These patients also have a higher risk of postoperative myocardial infarction and are twice as likely to develop wound infection and a thromboembolic event.

Secondary to the pathophysiological changes and surgical complications of obesity, these patients are regarded as challenging anesthesia cases requiring additional management considerations compared to those with a normal BMI. Another issue with obesity is a much higher incidence of chronic pain, and therefore, many of these patients need sedation, often in the prone position for interventional pain procedures.

Seeing that the population of patients with obesity continues to rise, anesthesiologists should become familiar with and adept at handling the issues associated with these patients, including utilizing safer strategies when delivering sedation and utilizing best practice techniques intraoperatively and postoperatively. The present investigation, therefore, describes pathophysiology, surgery risks, anesthesia management, and complications following anesthesia of the patient with obesity.

### Pathophysiology of Morbid Obesity

Obesity is described as a complex multifactorial disease that accumulates excess body fat that leads to negative effects on health. Many factors contribute to the physiological effects of obesity. Genetics and the environment are the two most found traits that affect humans. Around 40%–70% of the obesity variation in humans results from genetic factors. Genetic obesity can be classified in three ways: monogenic, syndromic, and polygenic. Monogenic results from a single gene mutation, primarily located in the leptin-melanocortin pathway. Syndromic stems from neurodevelopmental abnormalities and other organ system malformations. It may be caused by a single gene or a larger chromosomal region encompassing several genes. Lastly, polygenic is caused by multiple genes and results in excess weight gain and a higher calorie intake. People containing this type of genetic obesity often favor food, have increased hunger levels, reduced control overeating, reduced satiety, increased tendency to store body fat, and increased tendency to be sedentary. Epigenetics may offer a logical explanation for increasing obesity prevalence over the past few decades without necessitating a radical change in the genome. On the contrary, it is suggested that the global rise of obesity is largely due to environmental
factors such as high food consumption, high sweetened beverages, less activity, television watching, and numerous other factors."^{[13]}

The pathophysiology of obesity involves a complex interplay of obesogenic factors, including those alterations in central nervous system (CNS)-endocrine signals. The CNS detects information related to metabolic needs of adipose tissue, liver, stomach, muscles, and bones. The positive energy balance produced by the sympathetic nervous system (SNS) increases the volume of skeletal muscle liver, among other organs and tissues of the body. Concerning this, an obese individual with stable weight, compared with an individual with normal BMI, hence has greater fat and lean mass, which results in higher resting energy expenditure, cardiac output, blood pressure, and greater pancreatic β-cell mass. Obesity also causes profound microbial changes, and gut microbes impact the host metabolism affecting inflammation, fat deposition, and insulin resistance. There are many comorbidities that obesity aids. Some examples include Cushing’s syndrome, kidney dysfunction, esophageal complications, congestive heart disease (CHD), Alzheimer’s disease, infertility, immune system dysfunction, arthritis, OSA, and asthma, along with many others not listed."^{[14]} From a medical standpoint, obesity is a weighing factor on the ability to perform lifesaving procedures, mostly which require the patient to be under anesthesia. At higher body weight, the odds of difficult tracheal intubation, which was defined as requiring more than one attempt with direct laryngoscopy (DL), were greater in patients with obesity compared to lean patients. Propofol is the most frequently used drug for the induction of general anesthesia, but the appropriate dosing in patients with obesity remains controversial. Although bolus dose recommendations based on actual or total body weight (TBW) are valid in normal-weight patients, large doses based on TBW in morbidly patients with obesity can potentially be dangerous."^{[15]}

**Obesity Surgery Risks and Anesthesia Complications**

It is widely known that undergoing surgery and anesthesia comes with risks. When an individual is overweight, those risks are increased. In the case of the super-morbidly obese subject, when a person has a BMI >50 kg/m², many more factors can cause complications. These can be caused by the physical aspect of excess tissue or the metabolic changes in these individuals.

Obtaining intravenous access for the administration of drugs during general anesthesia is a basic requirement. This is complicated when a patient has excess adipose tissue, limiting visualization. In a non-emergent situation, ultrasound can guide the intravenous cannula. However, losing access during a procedure or an emergency situation becomes more dangerous for the patient related to delayed administration of appropriate drugs and resuscitation measures.

Another situation complicated by the physical aspects of anesthesia is airway management. When there is excess tissue surrounding the neck, the range of motion becomes limited, complicating proper and safe intubation techniques. People in this population also have increased weight which surrounds and compresses the air passages internally. When the patient is lying supine, or the nerve stimulation that is holding the laryngeal muscles taut becomes blocked during induction, there is a risk that the airflow decreases or stops altogether. The time that a patient spends in this situation can be reduced with video laryngoscopy, proper planning, and positioning. However, patients with obesity are known to desaturate quicker, which is a crucial and dangerous part of the patient undergoing any surgery requiring general anesthesia."^{[4]}

OSA is common underlying and often undiagnosed comorbidities in the obese population. It is estimated to affect 40%–90% of these individuals."^{[4]} It has systemic effects with detrimental manifestations and is vitally important when considering management under anesthesia. In OSA, an individual has chronic respiratory acidosis secondary to hypercapnia and hypoxia from impaired ventilation during rest. Hypoxia causes vasoconstriction of the pulmonary circuit. Since obesity already increases blood flow as much as 2–3 ml/min/100 g, the outcome can be severe pulmonary hypertension."^{[16]} When the transpulmonary pressure increases, it also increases the left ventricular filling pressure. The strain on the ventricle causes pathological cardiac remodeling and fatty infiltration into the conduction system, leading to nodal dysfunction. When this happens, there is an increased risk for atrial fibrillation. According to Schinjins et al., for every one BMI point increase, there is a 4% increased risk for the development of atrial fibrillation."^{[17]}

Another complication of OSA in patients with obesity is the decreased respiratory drive from frequent episodes of apneas leading to chronic hypercapnia and hypoxemia. This causes increased risks of complications when extubating the patient. If the patient desaturates severely, reintubate may be needed."^{[18]} Postoperative pain management can also become complicated because of the baseline risk of respiratory depression. Although postoperative pain management is standardly treated with opioids, these cause respiratory depression. Therefore, they should be avoided when possible. Other pain management modalities that are recommended are nerve blocks, acetaminophen, and the use of non-steroidal anti-inflammatory medications. However,
nerve blocks are complicated in patients with excess tissue, as in the case of the super-morbid obese, due to limited access and exposure to the underlying nerves.\[^4\]

Drug administration in this patient population is particularly problematic. In general, the drug company calculates the dosage required by the individual’s weight. This is based on an average individual’s Lean Body Weight (LBW) vs. Total Body Weight (TBW). However, in the super-morbid obese, this ratio is skewed, indicating a risk for improper calculations in the administration of medication dosage. This is exacerbated in fat-soluble drugs, as the volume of distribution and clearance is altered. Another factor that plays a role in a drug’s activity is “binding.” Chronically, patients with obesity are often found to have metabolic syndrome, a classically described when an individual has excess fat and carbohydrate accumulation in the liver over long periods of time, leading to non-alcoholic steatohepatitis. Once the system becomes overloaded, it also becomes dysregulated as there is an increase in the serum insulin, glucose, and fatty acids.\[^{[19]}\] These excess molecules in the serum alter the binding of the drugs with albumin and other molecular transporters. In renally excreted drugs, there is an increase in the elimination. However, drugs that are metabolized through the liver have decreased elimination secondary to the damage caused by the fat accumulation.\[^4\]

Asthma is another common comorbid condition that can cause complications during anesthesia in the obese population. Although it remains to be definitively decided if obesity causes asthma, it is known that it does worsen the disease and increases the difficulty in treatment.\[^{[20]}\] The worsening of asthma is hypothesized to be caused by the increase of adipokine release and the shallower breathing done in obese individuals related to the excess weight surrounding their chest cavity that promotes narrow airways. Both exacerbate an asthma attack. Although it is not common in the normal asthmatic population to have an asthma attack or bronchospasm during anesthesia, it can be life-threatening. This becomes complicated in the situation of the super-morbid obese patient who also has alterations in the drug responsiveness. Theophylline and beclomethasone were both found to be less effective in patients with obesity, whereas montelukast was found to be a stable treatment option.\[^{[21]}\]

**Obesity and Anesthesia Management**

Patients who are obese have anatomical and physiological differences from normal-weighted patients, which must be accounted for when undergoing anesthesia and surgical procedures. Medical conditions associated with obesity such as OSA, diabetes mellitus, hypertension, hyperlipidemia, gastroesophageal reflux disease (GERD), coronary artery disease, osteoarthritis, and liver disease can all complicate surgical procedures. A thorough assessment of comorbid medical conditions is essential and should be completed in the preoperative period to reduce the risk of complications and increase efficiency during the operation.\[^{[22]}\] This obese patient population has physical characteristics that make intraoperative management more challenging and comorbidities that increase their perioperative mortality risk. Physiologic properties such as increased neck diameter, decreased functional residual capacity (FRV), decreased expiratory reserve volume (ERV), and reduced cardiac reserve can complicate airway management and increase the risk of intraoperative decompensation.\[^{[22]}\]

Proper positioning is an important aspect of intraoperative management because it can optimize circulation and oxygenation, aid in procedures such as endotracheal intubation, and prevent nerve-related injuries.\[^{[23]}\] In this regard, injuries such as worsening osteoarthritis and positioning-related neuropathies from improper positioning are common in the obese population.\[^{[22,24]}\] Supine positioning in patients with obesity causes reduced FRC, lung compliance, and diaphragmatic movement that increases breathing, decreases lung volume, and causes hypoxemia and ventilation-perfusion mismatch.\[^{[25]}\] Prolonged operations with patients with obesity in the supine position should be avoided due to increased risk of glueteal rhabdomyolysis and decreased venous return due to compression of the inferior vena cava.\[^{[26,27]}\] Trendelenburg positioning is another unfavorable position for patients with obesity due to increased risk of atelectasis, hypoxemia, and exacerbation of limited cardiac reserve.\[^{[26,28]}\] Positions which patients with obesity better tolerate include prone, reverse Trendelenburg, lateral decubitus, and head-upward positioning. Prone positioning increases pulmonary compliance, FRC, and oxygenation in patients with obesity.\[^{[29]}\] Lateral decubitus, head-upward, and reverse Trendelenburg improve ease of intubation in patients with obesity; however, reverse Trendelenburg is associated with an increased risk of venous stasis.\[^{[23,29,30]}\]

Airway establishment can be more challenging in patients who are obese. However, patients with obesity do not all have difficult airways. There are proven factors related to obesity that are independent risk factors for difficult airways. Several studies show that sleep apnea, history of snoring, Mallampati class III and IV, increased neck circumference, limited cervical spine mobility, and increased BMI all increase the risk of difficult mask ventilation (DMV).\[^{[31–33]}\] Factors unrelated to obesity were also implicated, such as increasing age, presence of a beard,
lack of teeth, male gender, prior radiation treatment, and neck masses. Other studies have shown that difficult tracheal intubations (DTI) are more common in patients who are obese than patients who are not. One study found that a BMI over 30 kg/m² was associated with an increased risk of DTI. However, the difficulty did not increase as obesity increased in patients with BMIs above 30 kg/m². In addition to difficult DMV and DTI, patients with obesity reach critical hemoglobin desaturation during apnea more quickly than patients who are not obese due to decreased functional residual capacity, which is further decreased when these patients are supine. Different preoxygenation strategies have been shown to increase the time of oxygen desaturation to prolong safe apneic time. Preoxygenation with the patient positioned in a 25-degree head-up position, apneic diffusion oxygenation, and buccal King-Adair-Ewyn tube oxygen administration have all shown clinically significant prolongation of safe apneic time.

Airway management in patients with obesity should be approached individually for each patient in line with current recommendations and guidelines. Indirect laryngoscopy can be utilized to increase first-attempt tracheal intubation success, which is especially important in the obese population due to decreased safe apneic times. Direct laryngoscopy can also be successful with preoxygenation, correct blade size, and positioning. A randomized study comparing the two approaches in patients with BMI over 35 kg/m² found no significant difference between the time to intubation between the two. However, direct laryngoscopy was associated with an increased risk for failed intubation. Patients with anticipated difficult airways can be intubated while awake with flexible fiber-optic intubation, the gold standard for these scenarios.

After airway establishment, there are different strategies for ventilating patients with obesity during surgery. Ventilating patients with obesity poses unique challenges due to decreased respiratory compliance and oxygenation and increased propensity for atelectasis. No standard strategy has been established, but a systematic review by Souza et al. has demonstrated that patients who receive a combination of mechanical ventilation with alveolar recruitment maneuvers and positive end-expiratory pressure showed the most effective increase in oxygenation and respiratory compliance. A high degree of variability between strategies exists, and out of all the interventions, some were more effective than others, but none were associated with major complications or adverse outcomes.

Patients with obesity display different pharmacokinetics than BMIs in the normal range, requiring different doses of anesthetic medications. Lipid soluble drugs are metabolized faster in patients who are obese, and tissue distribution is also altered in these patients, which can lead to variable effects. Induction agents such as thiopental sodium and propofol are highly lipophilic and therefore have a much higher clearance rate in obese individuals, so the dose needs to be adjusted accordingly. The effects of opioids can also be altered in patients who are obese due to increased adipose tissue and increased body weight. Patients with obesity often experience slow recovery after using inhaled agents that are highly lipophilic due to the continued release of the drug from adipose tissue. Conversely, sevoflurane and desflurane have low lipid solubility causing rapid recovery in patients with obesity. Desflurane is the least lipophilic inhaled anesthetic and displays limited adipose tissue distribution; therefore, it is a favorable option for patients with obesity.

Postoperative Considerations in Patients with Obesity

Numerous studies in recent years have revealed higher postoperative complications in patients with obesity. Some of the major considerations include hypoventilation and sensitivity to opioids. In general, patients with obesity and super-super obese require a higher degree of monitoring. Many studies in recent years have demonstrated the beneficial role of pulse oximetry and quantitative end tidal CO2 monitoring to assess adequacy of oxygenation and ventilation. Although individual facilities worldwide vary in strategy, a major consideration should be utilizing this affordable technology in these higher risk patients as a best practice standard.

Pain Considerations and Regional Anesthesia in Patients with Obesity

Pain considerations can be challenging for several reasons, one is dosing but another factor is limited cardiopulmonary reserve. As previously described, patients with obesity have greater oxygen consumption requirements and are therefore more sensitive to sedatives and analgesics. One significant improvement in recent years has included the use of ultrasound guided nerve blocks, which provide effective targeted analgesia without delivering dose-dependent respiratory and central nervous system depressive effects. For many high-risk patients with obesity, anesthesia is provided without any opioids through targeting ultrasound guided nerve blocks. Regional anesthesia is generally a little more challenging but when employed successfully, it can provide a prudent strategy intraoperatively for many surgeries and procedures.
Conclusion

The epidemic of obesity has had far ranging public health implications. There is no field in medicine that has not seen affects from the vast increases in patients who are obese and super-super obese. With regard to anesthesia considerations, newer technologies have been helpful such as advanced airway devices and ultrasound-guided nerve blocks. Patients who are obese often have higher risk of complications intraoperatively and postoperatively, from sensitivities to sedatives and analgesics. Because of these risks, it is paramount that a thorough pre-operative assessment takes place to prevent any potential anesthesia-related complications. This includes an account of the patients’ comorbidities, proper airway assessment, and potential drug interactions. Numerous studies have advocated for limits in BMI in surgery centers as well as ongoing pulse oximetry and end tidal CO2 for safer monitoring of oxygenation and ventilation in these higher risk individuals. Studies have revealed certain interventions to be beneficial in patients with obesity intraoperatively, such as the reverse Trendelenburg and prone positioning, which may lead to better oxygenation and lower risk of position-based complications such as atelectasis, hypoxemia, and poor cardiac reserve. Thorough knowledge of physiological and anatomical parameters in this subset of patients may lead to better outcomes and a lower rate of complications. One such example is implementation of proper drug dosing and the use of less lipophilic anesthetics when applicable. Ultrasound guided nerve blocks may be a favorable option for pain management in these patients, precluding the dose-dependent respiratory decline associated with other commonly used modalities for pain control such as opioids. Given the steady rise of obesity around the globe, it is paramount that anesthesiologists become proficient with the modalities and specific management these high-risk patients require. A careful plan by the clinical anesthesiologist will provide a safe strategy to provide the best outcome for these challenging patients in the operating room, in interventional pain, gastrointestinal suites, and other areas where sedation and general anesthesia are required.

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