Anesthetic Implications of Obesity in the Surgical Patient

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ABSTRACT

The obese patient presents many challenges to both anesthesiologist and surgeon. A good understanding of the pathophysiologic effects of obesity and its anesthetic implications in the surgical setting is critical. The anesthesiologist must recognize increased risks and comorbidities inherent to the obese patient and manage accordingly, optimizing multisystem function in the perioperative period that leads to successful outcomes. Addressed from an organ systems approach, the purpose of this review is to provide surgical specialists with an overview of the anesthetic considerations of obesity. Minimally invasive surgery for the obese patient affords improved analgesia, postoperative pulmonary function, and shorter recovery times at the expense of a more challenging intraoperative anesthetic course. The physiologic effects of laparoscopy are discussed in detail. Although laparoscopy's physiologic effects on various organ systems are well recognized, techniques provide means for compensation and reversing such effects, thereby preserving good patient outcomes.

KEYWORDS: Obesity, anesthesia, laparoscopy, surgery

Objectives: Upon completion of this article, the reader should be able to summarize the anesthetic implications of obesity in terms of its physiologic perturbations, specifically with respect to laparoscopy.

Every clinician is aware of the complexity of caring for obese patients, the increasing prevalence of obesity, and the expected continuation of this trend. Although the anesthetic and surgical management of obese patients is more challenging, careful attention to comorbidities and risk factors enables most of these patients to be safely managed during the perioperative period.¹ Addressed from an organ systems approach, the purpose of this review is to provide surgical specialists with a review of the anesthetic implications of obesity, with special attention to laparoscopy.

AIRWAY MANAGEMENT

Morbidly obese (MO) patients have a higher potential for difficult mask ventilation, laryngoscopy, and intubation. The obese patient's large tongue, redundant oropharyngeal tissue, atlantoaxial joint limitation due to cervical and thoracic fat pads, and presternal fat deposits inhibit movement of the laryngoscope and increase the difficulty of direct laryngoscopy (DL). Factors such as a higher Mallampati classification (Fig. 1) and neck circumference^{2,3} are predictive of a difficult airway. In practice, the astute anesthesiologist integrates multiple

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Figure 1 Mallampati classification.

historic and physical clues such as thyromental distance, mouth opening, neck range of motion, and prognathism, to perform the preoperative airway assessment and predict conditions for airway management.

After airway evaluation, one of the following conclusions will be reached: (1) endotracheal intubation will most likely be feasible by DL, thus the airway can be secured after general anesthesia (GA) induction; or (2) endotracheal intubation will be difficult by DL, thus an awake intubation will be necessary. Fortunately, most of the obese patients' airways can be managed adequately after GA induction. The patient's position will need to be optimized for airway management. The head-elevated laryngoscopy position (HELP) uses preformed pillows to elevate the patient's upper body such that the external auditory meatus is in horizontal plane with the sternal notch, compensating for the fixed flexion brought about by cervical fat (Fig. 2).⁴ Regular blankets and towels available in any operating room can be used to achieve this same optimal positioning.

If inducing GA prior to intubation, it is very important to preoxygenate or denitrogenate the patient in preparation for the unavoidable period of apnea and potential oxygen desaturation prior to securing the airway (see Preoxygenation and Apneic Oxygenation section). Once the patient loses consciousness, the pharyngeal

musculature and the tongue relax, allowing for airway occlusion. Oral and/or nasal airways are often necessary to maintain a patent airway and to facilitate mask ventilation. Oral airways are preferred over nasal airways because the latter can cause bleeding that can obscure the visual field for intubation. Correct sizing and placement of airways are important, as improper technique can worsen the obstruction. For the obese patients with excess facial soft tissues, the two-hand technique for mask ventilation is necessary for effectiveness: one hand on each side of the face lifting the mandible toward the mask, thus creating a good seal while a second person is compressing the bag.

Proof of successful mask ventilation is a critical step in the airway management of a patient. Mask ventilation will keep a patient oxygenated and ventilated in the case of a failed intubation. Unless intentionally avoided in a rapid sequence induction (RSI, see later), the ability to mask ventilate is demonstrated after loss of consciousness and prior to the paralytic agent, as assurance that in the event intubation proves difficult, oxygenation and ventilation can be maintained while different approaches can be attempted to place the endotracheal tube (ETT). If intubation attempts are futile, then mask ventilation can be continued until the paralytic wears off or can be reversed and the patient is allowed to awaken.

The use of an appropriately sized laryngoscope is important for a successful intubation. The best blade (curved or straight) to use is the one with which the intubating person is most skilled.

In the patients where the airway looks highly unfavorable, an awake intubation is the best choice provided the patient is cooperative. The airway can be topically anesthetized by several means, the patient adequately premedicated, and the ETT placed either by an awake DL or more commonly, a fiberoptic bronchoscope. Once proper placement is confirmed, the patient is given a general anesthetic.

The worst-case scenario happens with an unexpected difficult airway in which both ventilation and intubation are difficult. In that situation, the laryngeal mask airway (LMA) remains a highly successful and

Figure 2 Head elevated laryngoscopy position (HELP) to optimize positioning for airway management.

Figure 3 The laryngeal mask airway (LMA).

appropriate rescue device for the difficult to ventilate patient (Fig. 3) until a more definite airway is obtained, which could include a surgical airway. The American Society of Anesthesiologists has published practice guidelines for the management of the difficult airway.⁵ The LMA can also be used as the airway device for the duration of surgery in selected patients. It works by fitting its cuff around the larynx for self-initiated respirations. It is unreliable for delivery of effective positive pressure ventilation. The LMA is often precluded in the obese by the higher risk for pulmonary aspiration associated with increased intraabdominal pressure, gastroesophageal reflux, and hiatal hernia. Obese patients will hypoventilate and de-recruit alveoli over time during spontaneous ventilation under GA. Thus, controlled ventilation with a secure airway, the ETT, is the most adequate option for this population.

RESPIRATORY

The obese patient has (1) decreased chest wall compliance due to adipose tissue deposition on the chest and abdomen, (2) decreased lung compliance due to increased pulmonary blood flow and viscosity, and (3) chronic hypoxemia. The decreased total pulmonary compliance leads to reduced functional residual capacity (FRC). The FRC provides for continued oxygenation of pulmonary capillary blood during exhalation. In the obese patient, closing capacity (capacity at which small airways begin to close) may approach the reduced FRC, resulting in airway closure with normal tidal volume respiration, leading the way for right to left shunting and arterial hypoxemia (Fig. 4). Also, supine positioning and anesthesia independently worsen this ventilation and perfusion mismatch. In addition, the obese patient utilizes increased oxygen consumption attributed to the metabolic demands of excess adipose tissue and impaired ventilation dynamics and efficiency. The clinical result of

Figure 4 Relationship of functional residual capacity (FRC), closing volume (CV), tidal volume breathing (zigzag) in awake and anesthetized obese patients. From Adams JP, Murphy PG. Obesity in anaesthesia and intensive care. *Br J Anaesth* 2000;85:91–108. Reprinted with permission of Oxford University Press.

the above factors is rapid arterial oxygen desaturation with apnea upon induction of anesthesia. The obese patient without obesity hypoventilation syndrome operates at small tidal volumes and increased respiratory rate to increase minute ventilation for maintenance of normocapnia. This strategy produces the least oxygen cost. Techniques used to optimize the respiratory system in an obese patient include head up position,⁶ positive end expiratory pressure (PEEP), larger tidal volumes, and high fraction of inspiratory oxygen. It must be noted that the potentially deleterious hemodynamic effects of these maneuvers can offset some of the benefit on arterial oxygenation.

PREOXYGENATION AND APNEIC OXYGENATION

Preoxygenation, or denitrogenation, is a simple preventive step that can help delay or avoid harmful consequences secondary to airway problems, especially in the obese population. The increased intraabdominal pressure and derecruitment of dependent alveoli combined with a restrictive ventilatory pattern and elevated oxygen consumption lead to rapid oxygen desaturation after induction of anesthesia.⁷ As such, every effort to prolong the period of adequate saturation with initiation of apnea must be employed, especially given the association with difficult intubation and mask ventilation. Thus, replacing the nitrogen in the inhaled air with oxygen during the “denitrogenation” period increases the available oxygen reserve in the lungs. The most common technique is for the patient to spontaneously breathe 100% O₂ at high flows by a snug-fitting face mask until the end-tidal (Et)O₂ is >80% while lying supine in the HELLP position. This technique is easy to perform and should be routine.

Apneic oxygenation describes the continued application of oxygen, despite apnea, to prolong the period

to desaturation. The rationale is to continue to fill the FRC with passive movement of O₂ despite apnea. First described by Frumin, Epstein, and Cohen in 1959⁸ through an ETT, it can also be done by a tight-fitting mask, an LMA, the side port of a rigid bronchoscope, or even through a regular nasal cannula.⁹ Frumin's patients remained oxygenated at >98%, ranging 18 to 55 minutes, with the study stopping because of arrhythmias seen; the PaCO₂ ranged from 130 to 160 mm Hg as it accumulated during apnea.

The extra time to desaturation allowed by these techniques becomes very important when airway management is difficult and the possibility of hypoxic brain injury becomes very real. It is important to mention that while oxygen saturation is maintained, the PaCO₂ rises 6 mm Hg the first minute and 3 mm Hg per minute thereafter without ventilation.

OBSTRUCTIVE SLEEP APNEA

Obstructive sleep apnea (OSA) is a serious comorbidity of obesity that is often underestimated. It is associated with difficulty in effective mask ventilation, hypoxemic events, coronary artery ischemia, arrhythmias, and sudden death, all of which are magnified in the context of anesthetic drugs. The postoperative, postextubation period is the most dangerous time because the residual anesthetics and pain medications impair the respiratory drive for hypoxemia and hypercarbia, worsens obstruction, and leads to hypoventilation and adverse events. Many obese patients have undiagnosed OSA. The American Society of Anesthesiologists' Checklist¹⁰ and STOP Questionnaire¹¹ are available and have been validated¹² to identify patients with undiagnosed OSA. It is recommended that patients on home CPAP (continuous positive airway pressure) bring their device with them for immediate use postoperatively. It is recommended to have a CPAP device on standby during anesthesia recovery for those patients with suspected OSA.

For the patient with OSA, the anesthetic management focuses on minimizing the use of opiates, benzodiazepines, and other respiratory drive-suppressing drugs. Regional anesthesia and nonopioid adjuvants take a prominent role. For outpatient surgery, the American Society of Anesthesiologists Practice Guidelines¹⁰ indicate a 3-hour additional observation period for patients suspected of OSA, or 7 hours after the last event of obstruction or hypoxemia, before discharge home. This guideline implies that a single event of oxygen desaturation, in all but the earliest cases, would necessitate overnight observation.

CARDIOVASCULAR

The MO patient has an increase in both total body weight and lean body mass contributing to increased

metabolic demands, resulting in a larger total blood volume. The increased blood volume and the decreased systemic vascular resistance common in obese patients lead to increased cardiac output. Stroke volume is increased while heart rate remains more or less unchanged. Wall stress of the left ventricle is elevated as a result of the increased circulating volume, leading to compensatory concentric hypertrophy and resultant diastolic dysfunction over time. Systolic dysfunction may follow, leading to pulmonary hypertension. The MO patient, at risk for OSA, is already predisposed to high pulmonary pressures, right ventricle failure, and atrial dysrhythmias (Fig. 5). For patients suspected of OSA, an electrocardiogram as well as a detailed cardiopulmonary history and functional status should be part of the initial screening. Further studies combining arterial blood gas analysis, chest x-ray, and echocardiogram provide more insight into these abnormalities so preoperative optimization and risk-lowering interventions can be implemented and help the anesthesiologist to formulate the optimal perioperative anesthetic plan.

GASTROINTESTINAL

Morbidly obese patients are generally considered to be at increased risk for aspiration of gastric contents with induction of anesthesia. This seems reasonable given the population's increased abdominal pressure, association of hiatal hernias, and gastroesophageal reflux disease. Interestingly, MO patients are found to have faster gastric emptying, but still have a larger residual volume after an NPO (nil-per-os; nothing by mouth) period because of a larger gastric volume. Additionally, increased ventilation pressures during possible difficult mask ventilation predisposes to regurgitation from gastric insufflation. Considering these factors, many anesthesiologists will premedicate the patient with prokinetic agents, H₂-receptor antagonists, or proton pump inhibitors, and nonparticulate acid neutralizers to minimize the impact of an aspiration event. Also, a rapid sequence induction (RSI) with early intubation is considered if the airway is deemed feasible. An RSI describes the induction process in which a quick-onset induction agent is followed immediately with a quick-onset paralytic in the presence of cricoid pressure and immediate intubation of the airway. No mask ventilation is performed prior to the paralytic agent being given. The purpose of an RSI is to minimize the duration of an unprotected airway, thus minimizing the chances for passive aspiration of stomach contents. The disadvantage of RSI is the paralysis of the patient prior to proving the feasibility of ventilation, such that the patient loses the ability to self-rescue if the airway falls into a "can't ventilate—can't intubate" scenario.

Figure 5 Potential progression of cardiovascular changes in obese patients. From Adams JP, Murphy PG. Obesity in anaesthesia and intensive care. *Br J Anaesth* 2000;85:91–108. Reprinted with permission of Oxford University Press.

PHARMACOLOGY

Obesity alters the pharmacokinetics of most drugs. Also, obese patients exhibit altered responses to some medications, for example, an increased sensitivity to the respiratory depressant effects of benzodiazepines and other sedatives. Drug-dosing regimens for obese patients based on ideal body weight (IBW) will lead to underdosing. Alternatively, dosing on total body weight (TBW) will generally lead to overdosing, or a prolonged therapeutic effect.¹³ Dosing based on lean body mass (LBM) has been proposed to be a good approximation to reach adequate drug levels, but in the MO patient may lead to underdosing.¹⁴ Lean body mass (LBM) is the total body mass minus the mass of fat; it is approximately the IBW plus 20 to 40% of the excess body weight. It can be determined by different methods and equations based on TBW and height. Dosing on LBM can be a starting point, followed by titration to desired pharmacologic effects, taking into account repeated doses can lead to prolonged effects. Shafer^{14a} proposes the following technique to simplify calculation and still mostly account for the pharmacokinetic differences in obese patients: for BMI <35, use IBW plus 40% of the TBW–IBW difference, for BMI between 35 and 45, use IBW plus

30% of the TBW–IBW difference, and for BMI >45, use IBW plus 20% of the TBW–IBW difference. Note that these are generalizations.

Soluble inhalational agents accumulate in adipose tissue and take longer to clear, resulting in more prolonged emergence as compared with less-soluble agents.

POSITIONING

Positioning the obese patient can prove to be a challenge for the operating room team. Ulnar neuropathy, although also reported in nonsurgical inpatients, is the most frequently reported perioperative positioning complication and with higher frequency in the obese population.¹⁵ The American Society of Anesthesiologists' Taskforce on Prevention of Perioperative Peripheral Neuropathies includes specific recommendations to curtail the risk of perioperative ulnar neuropathy.¹⁶ The Taskforce recommends padding and avoidance of flexion at the elbow, and a neutral or supinated position. However, such precautions have not been clearly shown to reduce the incidence of neuropathy, as it still occurs even with supination and appropriate padding. Neuropathy of other nerves has also been reported. Chronic micro-nutrient deficiencies seem to also contribute to this

problem. Careful and appropriate positioning of all body areas must be repeatedly reevaluated by the vigilant anesthesiologist, as changes in operating table position, members of the surgical team leaning against the patient, and spontaneous movement of the patient may lead to undesirable positioning outcomes.

PAIN MANAGEMENT

Effective postoperative pain control should be mandatory in any surgical process. Achieving adequate pain control in the obese patient can be challenging. Opioids are the mainstay of analgesic therapy for postoperative pain control; however, they are associated with sedation and respiratory depression, which coupled with the obese patient's risks of OSA, sensitization to the depressant effects of opioids, and dosing challenges, lead frequently to undertreatment of pain. The most effective regimens for pain control involve multimodal techniques. For an open procedure, epidural analgesia supplemented by nonsteroidal antiinflammatory drugs (NSAIDs) and acetaminophen provides effective pain control without the side effects of opioids. Local anesthetics continuously delivered by catheters in the wound site with adjuvant nonopioids can effectively provide adequate analgesia while minimizing the use of opioids.¹⁷ Intravenous patient-controlled analgesia of opioids in a monitored setting as part of a multimodal approach allows more even blood levels and better control of pain, and it can provide effective pain management both for open procedures and laparoscopic approaches.

LAPAROSCOPY

The deleterious physiologic effects of capnopneumoperitoneum are mainly related to abdominal insufflation and the effects of absorbed carbon dioxide. Data for obese patients are limited, and come primarily from populations undergoing laparoscopic gastric banding. Laparoscopic surgical procedures in the obese patient are frequently technically more difficult, thus exposing these patients to prolonged physiologic disturbances.

Laparoscopy and Pulmonary Physiology

Pneumoperitoneum results in atelectasis, reduction in FRC, and decreased compliance resulting in higher airway pressures. These changes can impede oxygenation and ventilation. In addition, the inevitable absorption of carbon dioxide (CO₂) requires compensation in the form of increased ventilation to maintain normocapnia. Lower subcutaneous tissue oxygenation has been reported in the MO patient; some authors advocate using FiO₂ of 0.80 to maintain adequate tissue oxygenation and decrease the risk of wound infection during bowel surgery in the obese patient.^{18–20} It appears that absorption of CO₂

from capnopneumoperitoneum is not significantly different in the obese.^{21,22} Although excessive hypercarbia can be detrimental in this patient population, Hager et al found that permissive mild hypercapnia, EtCO₂ 50 mm Hg versus normocapnia EtCO₂ 35 mmHg, was associated with higher mean subcutaneous tissue oxygen in the morbidly obese while FiO₂ was maintained at 0.80. Although pH in the hypercarbic group averaged 7.29, no clinically detrimental effects of hypercarbia were observed.²³

Cardiovascular Effects of Laparoscopy

The data overall on the effects of pneumoperitoneum on the cardiovascular system of obese patients suggests a less-significant effect in the obese population.^{24–26} One theory is that although similar insufflation pressures are used for both obese and nonobese patients, the MO patients have higher baseline intraabdominal pressures,²⁷ so a lesser cardiovascular effect of pneumoperitoneum may be seen. Obese or nonobese, it is important to maintain an adequate intravascular volume prior to abdominal insufflation to lessen these cardiovascular changes.

As expected, pneumoperitoneum has been shown to reduce hepatic blood flow,²⁸ and perioperative increases in transaminases after laparoscopy have been reported. This must be considered as the obese patient often has some degree of liver impairment, such as nonalcoholic steatohepatitis. Also, intraoperative urine output is diminished by pneumoperitoneum in both obese and nonobese populations, but no elevations of creatinine or decreased creatinine clearance were noted, even in obese patients.²⁷ The use of sequential compression devices is important to counteract the reduction in femoral venous flow during pneumoperitoneum for prevention of deep venous thrombosis.

Shortening the operative time is an important factor in reducing the patient's exposure to laparoscopy's adverse consequences.

CONCLUSION

The rising prevalence of obesity translates into more obese patients presenting for surgery. Despite the higher risks and anesthetic challenges associated with this patient population and the additional physiologic perturbations imposed by capnopneumoperitoneum and surgery, laparoscopic procedures are increasingly performed. Surgery and anesthesia can be safely done in morbidly obese patients with normal cardiac, pulmonary, renal, and hepatic function.

For the high-risk obese patients with severe multisystem disease, good outcomes are also possible, provided the entire perioperative team is well aware of the comorbidities of the patient and associated inherent

risks of surgery and anesthesia, and they strive to work together toward the optimization of the patient's condition at every step of the process.

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