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Perioperative management of the obese patient

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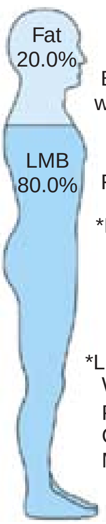
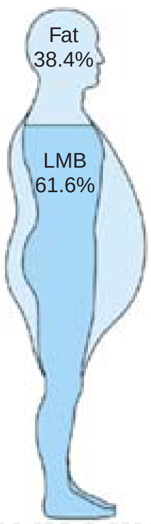
Obesity has become a world-wide epidemic in both industrial and developing nations. The precursors of obesity include gender, genetics, environment, ethnicity, education and socioeconomic status. Obesity related medical conditions are reversible following surgical weight loss. Laparoscopy is the preferred operative approach since it is associated with less postoperative pain, earlier recovery and reduced risk of postoperative pulmonary complications. Surgical options currently include either strictly restrictive procedures (vertical banded gastroplasty, adjustable gastric banding) that limit stomach capacity, or operations that combine gastric restriction and malabsorption (Roux-en-Y gastric bypass, biliary-pancreatic diversion, duodenal switch).



	Non-Obese kg	Non-Obese %	Obese kg	Obese %
Body weight	70 kg		105 kg	
Fat	14.0	20.0	40.3	38.4
*LBM	56.0	80.0	64.7	61.6
	70.0	100.0	105.0	100.0
*LMB				
Water	41.0	58.6	47.4	45.1
Protein	11.5	16.4	13.2	12.6
Glycogen	0.5	0.7	0.5	0.5
Mineral	3.0	4.3	3.6	3.4
	56.0	80.0	64.7	61.6



Total body weight (TBW) is composed of lean body mass (LBM = muscles, bones, tendons, ligaments and body water) and fat weight (FW). LBW should be about 80% of TBW for males and 75% of for females. Obesity is present when FW > 30% TBW. Ideal body weight (IBW) is a measure initially derived from life insurance studies to describe weight statistically associated with maximum life expectancy. For men and women IBW can be calculated as 22 x height (m^2). Normal weight ranges between ± 10% of IBW.

Two general types of obesity are described. In "central-android" obesity (more common in men) fat is located in the abdomen and upper body. In "peripheral-gynecoid" obesity (more common in women) fat is located primarily in the hips, buttocks and thighs. Central-obesity is associated with the "metabolic syndrome" with an increased risk of cardiovascular disease.

Body mass index (BMI), an indirect measure of obesity, is calculated by dividing weight in kilograms (kg) by square of height in meters (m^2). BMI does not consider gender or other contributing factors (water, muscle) as causes of increased TBW. A BMI of 20-25 kg/m^2 is defined as normal weight, and BMI of 26 - 29 kg/m^2 is "overweight". BMI > 30 kg/m^2 is "obese". "Morbid obesity" describes obesity that, if untreated, will significantly shorten the patient's life. A BMI > 40 kg/m^2 is "morbid obesity". A patient with a BMI > 36 kg/m^2 and multiple medical co-morbidities is considered a candidate for bariatric surgery.

Metabolic Syndrome (Central Obesity)

Three or more of the following must be present:

- Waist circumference > 102 cm (men), > 88 cm (women)
- Serum triglycerides > 150 mg/dL
- HDL cholesterol < 40 mg/dL (men), < 50 mg/dL (women)
- Systolic blood pressure > 130 mmHg and/or diastolic > 85 mmHg, or, on treatment for

PREOPERATIVE EVALUATION

Morbidity and mortality doubles with a BMI > 35 kg/m^2 and rises exponentially with increasing BMI. Obesity is associated with many chronic medical conditions that must be recognized and optimized before surgery. Endocrine conditions such as Cushing's disease, hypothyroidism and polycystic ovary syndrome are also associated with obesity. A patient scheduled for any surgery following previous bariatric surgery should be evaluated for metabolic changes, including protein, vitamin, iron and calcium deficiencies.

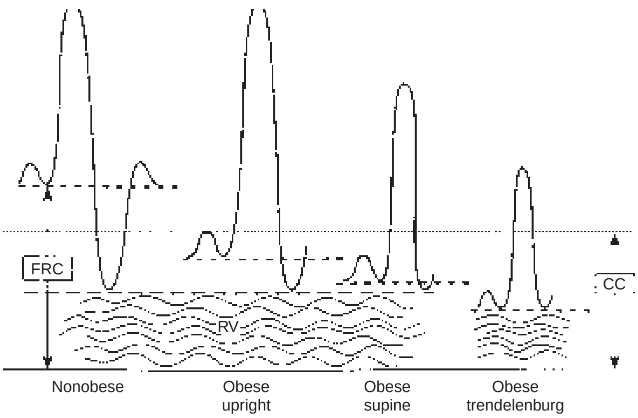
Preoperative diagnostic testing

Routine tests
Thyroid function
Lipid profile
Glucose
Liver function tests
Creatinine
ECG
Special tests
Dexamethasone suppression test
Testosterone level
RUQ ultrasound
Sleep studies
ECHO (h/o heart disease or Fen/Phen)
Cardiac stress test
Pulmonary functions tests

Medications: All recent medications, including non-prescription diet drugs must be identified since many have important implications for anesthesia. The combination of phentermine and fenfluramine ("Phen-Fen") is no longer prescribed, but phentermine is still used world-wide. An association between Phen-Fen and heart and lung problems has been clearly established. These medications must be stopped 2 weeks before surgery and a complete cardiac evaluation obtained. Sibutramine works in the brain by inhibiting reuptake of nor-epinephrine, serotonin and dopamine, producing a feeling of "anorexia" limiting food intake. It can cause arrhythmias and hypertension. Orlistat blocks absorption of dietary fat causing deficiencies in fat-soluble vitamins (A, D, E, K). Reduced vitamin K level can increase the anticoagulation effects of coumadin.

Cardiovascular system: Cardiac output rises about 0.1 liter/min for each 1 kg addition in weight. Stroke volume is elevated since total blood volume increases to perfuse the added body fat. Increased cardiac output combined with normal peripheral vascular resistance leads to systemic hypertension. A 3-4 mmHg increase in systolic pressure and a 2 mmHg increase in diastolic arterial pressure can be expected for every 10 kg of weight gained. Increases in blood volume and cardiac output eventually produce dilational cardiac hypertrophy. Left ventricular dysfunction is often presents. Even normotensive patients have increased preload, after-load, mean pulmonary artery pressure (PAP), and an elevation in right and left ventricular stroke work. These patients are often not physically active and may appear asymptomatic even with significant cardiovascular disease. Signs of pulmonary hypertension (exertional dyspnea, fatigue, syncope) should be sought and trans-esophageal echocardiography (TEE) obtained in symptomatic patients. Right heart failure is common in older patients.

Pulmonary system: Adipose is metabolically active and O_2 consumption and CO_2 production rise with increasing weight. The work of breathing is increased since more energy must be expended to carry additional body mass, while respiratory muscle performance is impaired. The fatty chest and abdominal walls reduce chest wall compliance. Mass loading of the thoracic and abdominal chest walls causes abnormalities in lung volumes and gas exchange. Functional residual capacity (FRC) is significantly reduced due to a decrease in expiratory reserve volume (ERV), so total lung capacity (TLC) is reduced. Airways close during normal ventilation. Continued perfusion of non-ventilated alveoli results in a PaO_2 that is lower than predicted for similar aged non obese patients. All these changes are directly proportional to increasing BMI. Younger obese patients have an increased ventilatory response to hypoxia. An arterial blood sample usually shows alveolar hyperventilation ($PaCO_2$ 30-35 mmHg) and relative hypoxemia (PaO_2 70-90 mmHg) on room air. With increasing age sensitivity to CO_2 decreases, $PaCO_2$ rises and PaO_2 falls.



Many patients maintain normal $PaCO_2$ during the day but have CO_2-retention, sleep disturbances, intermittent airway obstruction with hypoxemia, pulmonary hypertension and cardiac arrhythmia's at night. Obstructive sleep apnea (OSA) syndrome is characterized by frequent episodes of apnea (> 10 sec cessation of airflow despite continuous respiratory effort against a closed airway) and hypopnea (50% reduction in airflow or reduction associated with a decrease of SpO_2 > 4%). Patients may not be aware of these symptoms, so it is important to interview their spouses. A definitive diagnosis can only be confirmed by polysomnography in a sleep laboratory. Because of fragmented sleep patterns, patients may complain of daytime sleepiness and headaches. Chronic OSA leads to secondary polycythemia, hypoxemia, and hypercapnia; all increase the risk of cardiac and cerebral vascular disease. OSA patients can be difficult to mask ventilate, and their tracheas can be difficult to intubate. OSA patients requiring nasal continuous positive airway pressure (N-CPAP) at home should bring it to the hospital to use in the PACU.

A few patients experience the "obesity hypoventilation syndrome" characterized by somnolence, cardiac enlargement, polycythemia, hypoxemia and hypercapnia. Hypoventilation is central and independent of intrinsic lung disease, and is probably due to progressive desensitization of the respiratory center to CO_2 from nocturnal sleep disturbances. Its most severe form, "Pickwickian Syndrome", is characterized by marked obesity, hypersomnolence, hypoxia, hypercapnia, pulmonary hypertension, right ventricular enlargement and hypervolemia. Patients rely on a hypoxic ventilatory drive and may hypoventilate or become apneic during emergence from general anesthesia when given O_2.

Gastrointestinal and urinary systems: It was once believed that obese patients were at greater risk for acid aspiration because of increased intra-abdominal pressure, high incidence of GERD and hiatus hernia, and increased gastric volume with low gastric fluid pH. Recent work has challenged this belief. There were no differences in gastric volume or pH between lean and moderately obese surgical patients. Obese patients without symptoms of GERD have relatively normal gastro-esophageal sphincter tone and may have faster gastric emptying time. Patients at particular risk for gastric aspiration may be those with diabetes and gastroparesis. Non-alcoholic steatohepatitis (NASH), with or without liver dysfunction, is extremely common with histologic abnormalities present in the livers of as many as 90% of patients. Preoperative liver function tests may not reflect the actual severity of liver disease. Obesity is associated with increased renal blood flow and increased glomerular filtration rate.

OPERATIVE CONSIDERATIONS

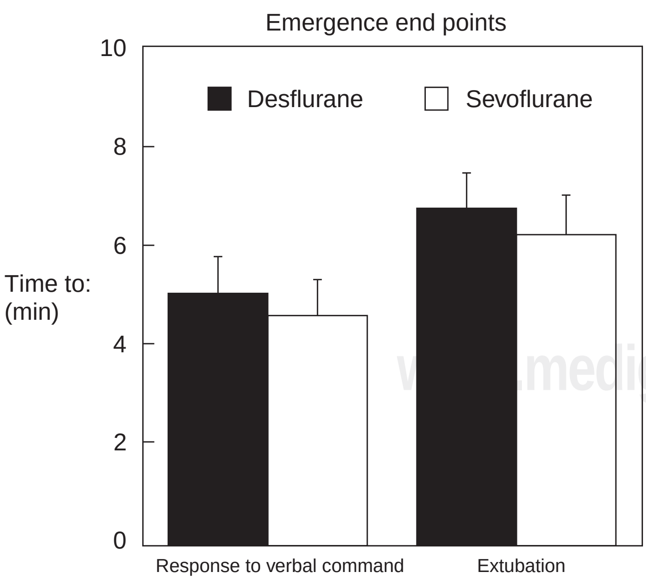
Premedication: Preoperative sedation is avoided. If fiberoptic bronchoscopic (FOB) intubation is planned an anti-cholinergic is given. Medications for chronic hypertension are continued; except ACE-inhibitors, which should be stopped preoperatively since their presence can lead to profound hypotension during anesthesia. Diabetic medications are usually withheld on the morning of surgery, but blood sugar must be closely monitored before, during, and after surgery. Prophylaxis with antibiotics for wound infection, and heparin against deep venous thrombosis (DVT) are administered prior to surgery. If concerned about risk of acid aspiration, H_2-receptor antagonists or a proton pump inhibitor can be given.

Positioning: When possible, we have the unpremedicated patient climb off the gurney and position themselves on the OR table. All pressure points are carefully padded to avoid pressure sores, neurologic injury, and rhabdomyolysis. In the supine position FRC is markedly reduced causing ventilation/perfusion (V/Q) mismatch, and significant increases in O_2 consumption, cardiac output, and PAP. The reverse Trendelenburg position (RTP) or a "head-elevated" position are best tolerated since the diaphragm is "unloaded" (Figure). Trendelenburg (TP) and lithotomy positions decrease lung volumes. In properly positioned prone patient ventilation is actually improved. The lateral decubitus position is tolerated if the panniculus is displaced off the abdomen.

Monitoring: For laparoscopy only standard monitors are applied. Non-invasive cuff pressure may be inaccurate if the wrong size cuff is used. If the anatomy of the upper arm doesn't allow proper fit, cuff pressures are obtained from the wrist or ankle. For laparotomy a radial artery is cannulated. Central lines (CVP, PA) can be useful for major abdominal and thoracic procedures. Since venous access is often limited a central line may be required for postoperative needs. A nerve stimulator is used to assess neuromuscular blockade. Excess fat may make surface electrodes inaccurate. A BIS monitor or another "depth of anesthesia" device can be useful.

Pharmacologic considerations: Physiologic changes in obesity affect distribution, binding and elimination of the various anesthetic agents. In routine practice on normal weight patients drugs are usually administered on the basis of dose per actual unit body weight. This assumes that clearances and distribution volumes are proportional to weight, which may not be valid in the obese patient. Obese patients have a smaller than normal fraction of total body water, increased blood volume and cardiac output, greater than normal fat content, increased LBW and changed tissue protein binding from increased concentrations of free fatty acids, triglycerides, lipoproteins, cholesterol and other serum constituents. In addition, renal blood flow and GFR are increased while cardiopulmonary function may not be optimal. Hepatic clearance is usually normal or even increased despite NASH. Highly lipophilic medications (barbiturates, benzodiazepines) have a significant increase in volume of distribution (Vd) and loading dose of these drugs is usually increased. Since elimination half-lives are longer, maintenance dosing should reflect IBW. Non- or weakly lipophilic drugs are given based on LBW. LBW is + 20-30% of IBW. Systemic absorption of oral medications is not significantly affected by obesity.

Inhalational agents: There is the misconception that release of volatile agents from the adipose tissue results in a prolonged emergence from anesthesia. Sevoflurane and desflurane have lower lipid solubility than isoflurane. Although reduced blood flow to adipose tissue may limit delivery of volatile agent to the fat and liver, and inhalational anesthetics are stored in the fat long after completion of surgery, all inhalational anesthetics are rapidly eliminated from the well-perfused brain and lungs once the anesthetic is discontinued. Despite claims that one agent is superior to another for bariatric operations, with proper timing, recovery from general anesthesia is similar with any inhalation agent (Figure) or TIVA technique.



Induction agents: Large doses of propofol or thiopental are needed due to increases in fat content, blood volume, and cardiac output. In theory dosing should be based on actual weight. However cardiovascular effects of large doses limit the absolute amount that can be given. Induction dosing is based on LBW.

Opioids: Opioids are highly lipophilic, and in theory loading doses should be based on TBW. There is no clinical evidence that lipophilic opioids last longer in morbidly obese patients. Generous use of long-acting opioids (morphine, demerol, hydromorphone) can be dangerous since respiratory depression must be avoided. The Vd of remifentanyl in obese patients is less than expected, probably because of hydrolysis by blood and tissue esterases. Dosing is based on IBW.

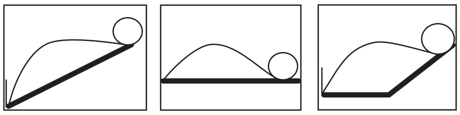
Muscle relaxants: Since pseudocholinesterase levels and extracellular fluid space are increased in obesity high doses of succinylcholine (1.0 mg/kg TBW) are used for induction. Complete paralysis is especially important during laparoscopy to facilitate ventilation and to provide adequate space for visualization and maneuvering of surgical equipment. Loss of pneumoperitoneum may indicate incomplete paralysis. Since muscle relaxants are hydrophilic there is limited distribution in the added fat. There are no clinical advantages between any of the non-depolarizing relaxants. Neuro-muscular recovery time is similar in obese and non-obese patients with atracurium, vecuronium or rocuronium. Muscle relaxants are administered in incremental doses based on IBW.

Fluids: Intraoperative fluid requirements are usually greater than would be anticipated for laparoscopy. We infuse 40 ml/kg IBW of crystalloid.

Airway management: Patients cannot breathe adequately in the supine or lithotomy positions, and they may be at risk for gastric aspiration. So tracheal intubation and assisted or controlled ventilation should be considered for even short procedures. Potential airway management problems (fat face and cheeks, limited range of motion of the head, neck and jaw, small mouth and large tongue, excessive palatal and pharyngeal tissue, short large neck, high Mallampati (III or IV) score) should all be evaluated preoperatively. Mallampati score and large neck circumference are the most reliable predictors of potential difficulties. If problems are anticipated FOB intubation is recommended. Increasing weight or BMI ***is not*** a risk factor for difficult laryngoscopy. Positioning with the head, neck and shoulders elevated in the head elevated laryngoscopy position ("HELP") facilitates direct laryngoscopy. FOB-assisted tracheal intubation is seldom necessary.

Despite conflicting evidence that patients are at greater risk for acid aspiration it remains prudent to establish a secure airway as quickly and as safely as possible. Patients

Table II. Desaturation and recovery times of groups.



Safe apnea	178 ± 55	123 ± 24	153 ± 63
Period (seconds)	(1 vs 3:p < 0.05)		
Recovery time	80 ± 30	206 ± 64	97 ± 41
(seconds)	(2 vs 1:P < 0.001)		(2 vs 3:P < 0.001)
Lowest SaO_2(%)	83 ± 4	82 ± 5	83 ± 4

Data is Mean ± Standard Deviation.

should be pre-oxygenated in the reverse Trendelenburg position (RTP) (Figure) until their SpO_2 is 100% for several mins. An apneic patient's hemoglobin will desaturate very quickly since FRC is reduced and O_2 reserves are limited. An i.v. induction with propofol and succinylcholine and cricoid pressure is the best way to establish an airway. A second individual experienced with airway management, preferably another anesthesiologist, must always be present to assist if difficulty is encountered with mask ventilation or tracheal intubation. Aids for difficult intubation must be readily available, including a short laryngoscope handle and a variety of laryngoscope blades and a gum elastic bougie. A laryngeal mask airway (LMA) can serve as a 'bridge' until an endotracheal tube is placed.

Ventilation: Obese patients should be mechanically ventilated with at least 50% O_2 and a tidal volume (Vt) 12-15 mL/kg IBW, preferably in the RTP. With mechanical ventilation, especially during laparoscopy, peak ventilatory pressures and end-tidal CO_2 levels will increase. PEEP superimposed upon a large Vt can worsen hypoxemia by depressing cardiac output, which in turn will reduce O_2 delivery to the tissues. Placement of sub-diaphragmatic packs or retractors or changing to lithotomy or TP will also worsen hypoxemia. Obese patients tolerate abdominal insufflation during laparoscopy without serious impairment of respiratory mechanics. Although absorption of insufflated CO_2 can worsen hypercarbia and produce acidosis, changes are temporary and are usually well tolerated, and need not be corrected. The surgical pneumoperitoneum can displace the diaphragm cephalad causing endotracheal tube position to change, with the tip entering a bronchus. Tube displacement should always be considered in the differential diagnosis of hypoxemia developing during laparoscopic bariatric surgery.

Hemodynamic changes: Pulmonary capillary wedge and PAP pressures may be elevated secondary to increased pulmonary blood volume and chronic hypoxemia. The RTP will improve oxygenation but may also cause pooling of blood and hypotension.

Regional anesthesia: Regional blocks can be technically challenging. Special long epidural and spinal needles may be needed. Insulated needles and a nerve stimulator can be used to identify the appropriate nerves for peripheral nerve blocks. Neuraxial spread of local anesthetics is directly related to BMI. Increased abdominal pressure shifts blood from the inferior vena cava into the epidural venous system decreasing the volume of the epidural and subarachnoid spaces. Epidural fat further reduces the capacity of the epidural space. For epidural and spinal blocks local anesthetic dose requirements are reduced by 20-25%.

Anesthetic technique: For laparotomy and thoracotomy, a combination of general anesthesia with epidural analgesia produces a lower incidence of postoperative respiratory complications and shorter hospital stays. Postoperative epidural opioid analgesia, with or without local anesthetics, is recommended. General anesthesia is maintained with an inhalational anesthetic. Long-acting opioids are used with caution or avoided completely to decrease the risk of postoperative respiratory depression. For laparoscopy we use a short-acting opioid infusion (remifentanyl) with small amounts of i.v. fentanyl. The patient is ventilated with an inhalational anesthetic agent and 100% O_2.

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