J Anesth (2012) 26:758–765
DOI 10.1007/s00540-012-1408-4

REVIEW ARTICLE

Anesthetic challenges in the obese patient

Rudin Domi · Haki Laho

Received: 14 December 2011 / Accepted: 23 April 2012 / Published online: 6 May 2012

Abstract Obesity seems to be the modern concern to society. An increasing number of obese patients present annually to surgical wards to undergo surgical procedures. As morbid obesity affects most of the vital organs, the anesthesiologist must be prepared to deal with several challenges. These include the preoperative evaluation of the consequences of obesity, particularly on cardiac, respiratory, and metabolic systems; airway management; different pharmacokinetic and pharmacodynamic drug regimen; and perioperative management (i.e., hemodynamic, respiratory, and hyperglycemic). This paper reviews and assesses the most important anesthetic issues in managing obese patients.

Keywords Obesity · Morbid obesity · General anesthesia

Introduction and epidemiology

Obesity is now considered the modern epidemic and is associated with serious problems faced by public health and clinical physicians. The incidence is increasing, and several nations report their statistics: In 2003–2004, 17.1 % of US children and adolescents were overweight and 32.2 % of adults were obese. According to the National Health and Nutrition Examination Survey data for 2007–2008, 68 % of American adults were obese, predominantly men [1]. The incidence reported in the UK and Australia is approximately 25 %, whereas in Japan, China, and in The Netherlands, 1:20 women and 1:10 men are classified as obese [2–5]. The World Health Organization (WHO) estimates that by 2015, 2.3 billion people worldwide will be overweight and 700 million will be obese.

Definition of obesity and overall preoperative morbidity risk

The definition of obesity and its clinical significance is well determined and accepted around the world. Obesity is defined as a body mass index (BMI) >30 kg/m^2. Table 1 summarized the values of BMI and nutritional status and obesity.

Pathophysiological changes range from airway management difficulties and changes in disturbances in respiratory physiology to many diseases as diabetes, hypertension, and heart disease. Morbidity rate increases substantially with increase in body weight, with subsequent increase in risks of hypertension, diabetes mellitus, coronary artery disease, dyslipidemia, gall bladder disease, osteoarthritis, respiratory problems, and cancers of various organs [6]. Related risks are surgical and medical. There are differences in the reported risk of surgery in the obese. Dindo et al. [7] reported that obesity did not pose a particular risk of morbidity or mortality for general elective surgery, but the mortality risk of gastric bypass surgery is high. Courcoulas et al. [8] reported a mortality rate 0.6 % and was as high as 5 % for surgeons doing less than ten procedures per year and 0.3 % if the surgeon did ten or more. Therefore, the more surgeries

R. Domi (✉)
Department of Anesthesia and Intensive Care,
University Hospital Center “Mother Teresa”,
Str Rruga e Dibres, 370, Tirana, Albania
e-mail: rudilaureta@hotmail.com

H. Laho
Department of Medicine, Bronx Lebanon Hospital Center,
Albert Einstein College of Medicine, New York, NY, USA

Table 1 Nutritional status and obesity based on body mass index (BMI)

Weight category classification	BMI (kg/m^2)
Underweight	<18.5
Normal weight	≥18.5–24.9
Overweight	≥25.0–29.9
Obesity	≥30
Morbid obesity	≥35
Supermorbid obesity	≥55

Table 2 Factors that can increase morbidity and mortality risk of the obese patient

Increased morbidity and mortality risk of obesity (not related with current diseases)
Greater body mass index
Android fat distribution
Urgent and major surgery
Gastric bypass surgery
Duration of obesity

performed by an individual surgeon, the lower the morbidity risk. Morbidity and mortality risk is proportional to obesity grade, duration, and form [9, 10]. Depending on fat distribution, there are two forms of obesity: an android form and a gynecoid form. The android form occurs when fat distributes centrally (liver, omentum, intraperitoneal), whereas the gynecoid form involves fat distribution in buttocks, arms, and legs. The android form is associated with a higher morbidity and mortality risk. Risk factors are summarized in Table 2. An interesting study [11] concluded that increasing BMI is associated with increased hospital mortality, intensive care unit (ICU) admissions, mechanical ventilation (MV), hospital stay, and costs. Table 3 presents results of the aforementioned studies.

Obesity-induced pathophysiological changes and anesthetic implications

Perioperative management of obese patients undergoing surgery for bariatric or other surgeries is difficult. Working as a team (anesthesiologist, surgeon, endocrinologist, nutritional physician, nurse) can guarantee a higher success rate and fewer complications.

Metabolism and fat distribution effects on anesthesia conduction

Obesity and fat distribution have several effects on metabolism and systemic organs. The fact that obesity increases the risk for cardiovascular, respiratory, and liver disease and has several metabolic consequences is well known. Obesity is often associated with diabetes, dyslipidemia, increased basal metabolic rate, greater oxygen consumption, and carbon dioxide production making the obese patient prone of rapid desaturation [12, 13].

Obesity-induced cardiac diseases and anesthesia risks

Obesity is associated with several cardiovascular effects. Obese patients tend to have increased blood volumes and increased risk of hypertension and ischemic heart disease. There is a strong correlation between BMI and blood pressure (BP) elevation, which in turn can be explained by different mechanisms (hormonal, renal, and hemodynamic). Approximately 60 % of obese patients may have mild to moderate systemic hypertension [14]. The reasons for hypertension include hypervolemia, increased cardiac output, increased peripheral vascular resistance, and hyperinsulinemia (causing sympathetic activation and sodium retention) [15, 16].

Progressive increases in BMI values may impair cardiac contractility, therefore decreasing the stroke volume and ejection fraction. This impaired cardiac contractility is usually due to hypertrophy and/or dilatation of the left ventricle [17]. These changes can be detected on

Table 3 Outcome parameters

Parameters	BMI 40–47.5 kg/m^2	BMI 47.6–54.6 kg/m^2	BMI 54.7–65 kg/m^2	BMI >65 kg/m^2
Mortality (%)	4.1	4.9	6.2	7.6
Need for ICU (%)	19.5	22.8	26.9	30.7
ICU admission (%)	28.3	32.5	32.7	38.3
ICU readmission (number of patients)	4	2	9	9
Need for MV (%)	9.5	12.9	17.6	19.6
Hospital stay (number of days)	3	4	4	5

BMI body mass index, *ICU* intensive care unit, *MV* mechanical ventilation electrocardiography (ECG) examination, as leftward shift of QRS axis, prolonged PR, QRS, and QTc [18]. Hypertension, increased heart rate, ventricular hypertrophy, diabetes, and—frequently—hypercholesterolemia can explain the ischemic heart disease often encountered in obese individuals. Obesity is now considered an independent risk factor for coronary artery disease. The incidence of right and left ventricle failure [19, 20] tends to be proportional with BMI. Heart failure happens when the stroke volume, cardiac output, and BP decrease due to impaired ventricular function. Obesity increases blood volume, stroke volume, and cardiac output. As a result, left ventricle enlargement may occur, increasing wall stress. The increased wall stress induces hypertrophy and then dilatation of left ventricle, impairing its diastolic and systolic functions. Due to obstructive sleep apnea (OSA), several changes can occur in the right ventricle. As a consequence of hypoxia and hypercapnia, pulmonary hypertension is often present, inducing right ventricle hypertrophy and then dilatation. These pathophysiological changes can explain the right ventricle syndrome and right ventricle failure. It is well known that ischemic heart disease can also impair both ventricular functions.

Airway management and respiratory changes during anesthesia in the obese

Several respiratory changes are present in obese patients [21–23]. Obesity reduces both pulmonary and total chest compliances. Decreased pulmonary compliance reduces functional residual capacity, which cannot overpass the closing capacity. As a consequence, obese patients are prone to increased intrapulmonary shunt V/Q mismatching. Thus, the obese patient may be hypoxic, with increased alveolar–arterial oxygen partial pressure $PAaO_2$, increasing the risk for postoperative atelectasis. General anesthesia and postoperative pain can precipitate these changes.

OSA is usually an associated disorder of obesity [24, 25] that results from the increased adipose tissue in the pharyngeal walls, increasing pharyngeal wall compliance. Studies [26, 27] suggest that between 40 % and 90 % of obese patients have obstructive sleep apnea. OSA is defined as a minimum of 10 s of total respiratory cessation that occurs more than 30 times a night. This explains the tendency of the pharyngeal wall to collapse during negative pressure on inspiration. These patients often complain of sleepiness, depression, and morning headache (hypercapnia) and often experience pulmonary hypertension, right ventricular failure, stroke, and hypertension. Nocturnal polysomnography (sleep study) can confirm the diagnosis. Decreased leptin [28] blood level (a frequent finding in obese individuals) makes the obese patient insensitive to carbon dioxide retention, producing the so called "obesity hypoventilation syndrome." This syndrome can deteriorate due to general anesthetics and sedative drugs and predisposes the patient to resting hypoxemia.

Airway management may be problematic. Small oral cavity, small mouth opening, large amount of adipose tissue, impaired joint movements (diabetes, adipose tissue), thick neck, impaired neck and head movements, and possible short sternomental or thyromental distances, are suggestive for difficult laryngoscopy and tracheal intubation. However, obesity does not correlate with difficult intubation but with difficult mask ventilation and postoperative respiratory failure. Several studies [29–31] report a weak relationship between obesity and difficult intubation. Lundstron et al. [32] analyzed 91,332 consecutive patients undergoing general surgery and tracheal intubation. They reported that BMI is a weak predictor for difficult intubation. Another study (The Australian Incident Monitoring Group) analyzed 2,000 patients and confirmed that BMI alone is not predictive of difficult intubation [33].

Obesity-induced gastrointestinal changes and diseases

Obesity can often be associated with hypercholesterolemia. Dyslipidemia can induce reversible fatty liver but occasionally progresses to steatohepatitis and cirrhosis [34]. The obese patient is also at risk of developing biliary tract disease, reflecting cholesterol metabolism disorder. A great incidence of gastroesophageal reflux disease (GERD) and hiatus hernia is reported. Increased intra-abdominal pressure may aggravate the reflux, increasing the risk of aspiration of gastric content. The mechanisms include an increased prevalence of esophageal motor disorders, diminished lower esophageal sphincter pressure, and increased intragastric pressure [35]. Diabetes is also an important disease associated with obesity as a result of insulin resistance in peripheral adipose tissue.

Perioperative thromboembolic events and stroke risks

Polycythemia, deep venous stasis, and increased intra-abdominal pressure double the risk for deep venous thrombosis (DVT) in obese individuals. Obesity has also been associated with an increased risk of pulmonary embolism, especially in women [36–38]. Each 1-U increase in BMI was associated with a multiple-adjusted increase of 4 % in the risk of ischemic stroke and 6 % for hemorrhagic stroke. Ischemic stroke severity seemed not to be associated with BMI [39].

Practical anesthesia conduction

General preoperative evaluation

Information on previous surgeries is useful to prepare the anesthetic plan and to foresee possible complications. It should focus on previous surgery and anesthetic problems, such as difficulties in airway management or intravenous access, ICU admission, possible MV, drug hypersensibility, etc. Preoperative evaluation should include consideration of cardiovascular and respiratory system (hypertension, heart failure, arrhythmias, obesity-related hypoventilation syndrome), and metabolic disorders (diabetes).

Cardiovascular evaluation [40] should include medical history (clinical signs suggestive for cardiac pathologies such as angina, dyspnea, headache, palpitations, activity capacity), clinical examination (cardiac tones, jugular vein, peripheral edema), and instrumental examination [electrocardiography (EEG), ECG, and coronary angiography if indicated). Respiratory system evaluation [41, 42] includes clinical (e.g., dyspnea) and imagining assessment. Chest X-ray examines heart size and pulmonary vasculature (for evidence of pulmonary hypertension). Blood gas analyses are useful to determine respiratory function and plan airway management. Functional respiratory test is useful to predict possible postoperative respiratory problems and determine the respiratory regimen during MV. Sleep study [41, 42] (nocturnal oximetry and polysomnography) is important in this context. Apnea Hypopnea Index (AHI) score >30 is a sign for rapid desaturation at induction. Recommended laboratory evaluations include blood glucose, lipid profile, serum chemistries (to evaluate renal and hepatic function and ferritin), and complete blood count. Liver-test abnormalities are common findings, being a determining factor for perioperative risk. Cirrhotic liver disease with portal hypertension is often considered a relative contraindication to bariatric surgery [41]. Dyspepsia indicates the presence of *Helicobacter pylori* and heart burn is significant to GERD, which requires preoperative medical treatment.

Monitoring and vascular access difficulties

BP [43] must be monitored using correct cuff size (40–45 cm) in order to give accurate values. Peripheral intravenous access may be difficult because of adipose tissue. Central venous catheter insertion is generally difficult due to hidden anatomical landmarks, but the procedure can be facilitated using ultrasound examination [44, 45].

Premedication and gastric aspiration risk prevention

Because of respiratory changes, it is advisable to avoid opioids, propofol, benzodiazepine, and oversedation for premedication purposes [46]. Sedation must be appropriate to the patient, the surgery, and the individual clinical protocol. The intramuscular route of administration must be avoided because of unpredictable absorption and effect. Gastric aspiration prevention is an important issue. Histamine (H_2) receptor blockers, metoclopramide, and sodium citrate are appropriate to reduce the risk of aspiration during anesthesia induction and endotracheal intubation.

Strategies of airway management

Obese patients must be examined for predictive signs of potential difficult intubation [47, 48], which may include Mallampati classification, thyromental and sternomental distances, small mouth opening, large protuberant teeth, limited neck mobility, retrognathia, and Wilson sum score. Based on several studies [49] on airway management of obese patients, the ramped position can guarantee easy intubation using conventional direct laryngoscopy. The equipment for emergency airway management, including laryngeal masks and a fiberoptic bronchoscope, should be immediately available. An awaked intubation sequence can be performed when a difficult intubation is predicted; the fiberoptic bronchoscope is a suitable choice for this purpose.

Effects of patient positioning

The supine position makes respiration more difficult by compressing the diaphragm, so the patient may need to have his/her back elevated. Abdominal pressure and weight can compress the inferior vena cava, which reduces venous return. The aorta increases the afterload, increasing blood pressure and decreasing stroke volume (when exaggerated). These changes are more significant when the Trendelenburg position is applied [50, 51]. The prone position is also not well tolerated and may have potential complications (skin breakdown, reduced respiration and circulation, nerve damage, eye or ear damage, damage to the breasts in women or genitals in men) [50, 51]. The potential hazards in the lithotomy position include skin breakdown, peroneal nerve damage, musculoskeletal injury (improper raising and lowering of the legs), and circulatory compromise (hypotension by lowering the legs). The lateral position is usually well tolerated by obese patients.

Anesthetic pharmacokinetics and dosage in obese patients

Several factors can affect the pharmacokinetic in obese patients. These include changes in the volume of distribution (decreased body water; increased fat, lean body mass, cardiac output, and total blood volume), increased

Table 4 Weight-based anesthetic dosing regimen

Anesthetic drug	Dosing regimen
Propofol	Induction: LBW; maintenance: TBW
Thiopental	Induction: IBW; maintenance: LBW
Fentanyl	TBW
Remifentanil	IBW
Succinylcholine	TBW
Vecuronium, rocuronium	IBW
Atracurium	IBW

TBW total body weight, *LBW* lean body weight, *IBW* ideal body weight

free-drug availability, and changes in clearance (increased renal blood flow and glomerular filtration rate; decreased hepatic blood flow). Drug dosage can be calculated on total body weight, BMI, lean body mass (ideal body mass +20 %), or ideal body weight. It is well known that pharmacokinetics of most anesthetics are usually determined by adipose tissue, producing a prolonged effect. The dosage of a lipophilic drug is connected to volume of distribution. The increased volume of distribution may prolong elimination—benzodiazepines and barbiturates—and dosages of these drugs must be calculated on ideal body weight or lean body mass if an infusion is to be used and according to total body mass when a single endovenous dose is needed [52]. For some muscle relaxants (vecuronium, rocuronium, cis-atracurium), ideal body mass should be used. Atracurium and succinylcholine are both calculated according to total body weight. Propofol has fast onset and short duration, making it the induction anesthetic agent of choice. Propofol, as a highly lipophilic agent, seems to have the volume of distribution and clearance proportional to total weight, so its dosage for continuous infusion should be calculated based on total body weight. Other studies [53, 54] conclude that for anesthesia induction, lean body mass is a more appropriate weight-based scalar for propofol. Fentanyl and sufentanil should be calculated on total body weight, whereas remifentanil [55, 56] should be based on ideal body weight. Dosages of almost all anesthetic drugs must be reduced. This is particularly important for obese patients with sleep apnea, who may be very sensitive to general anesthetics [57]. Table 4 summarizes the recommended weight-based dosing scalar for commonly used anesthetics.

Respiratory support during intubation, anesthesia, and postoperative period

Respiratory changes in obese patients discussed in the previous sections suggest that obese patients are prone to faster desaturation, increased rate of atelectasis, and need for ventilator support. There are many options to reduce respiratory complications. These include preoxygenation, continuous positive airway pressure (CPAP) application, and positive end-expiratory pressure (PEEP) during the intraoperative period. Preoxygenation prevents desaturation, which is much faster in obese than in normal-weight patients. The preoxygenation effect is augmented by 25° head-up position or by applying CPAP [58–60].

Tidal volumes based on actual body weight often cause alveolar overdistention and volutrauma. Using low tidal volumes (6 ml/kg) based on ideal body weight can decrease mortality risk in patients with acute respiratory distress syndrome, but several studies [61, 62] concluded that even the highest BMI group can benefit from low tidal volumes. The use of PEEP is also beneficial while ventilating morbidly obese patients, resulting in significant improvement in lung volumes, compliance, oxygenation, ventilation, and lower intra-abdominal pressure compared with no obese controls [63]. The addition of PEEP [64] to the head-up body position in 20 morbidly obese patients undergoing bariatric surgery decreased the alveolar–arterial oxygenation difference and increased respiratory system compliance. The obese patient needs careful ventilation management because of decreased thoracic compliance and secondary, possibly restrictive, respiratory dysfunction. These pathophysiological changes can contribute to increased airway pressure during intraoperative ventilation. The increased airway pressure may make the patient prone to ventilator-induced injury. The obese patient may be complicated by hypoventilation and atelectasis if not adequately ventilated but also by ventilator-induced injury if ventilator parameters are not properly chosen. The anesthesiologist must fix the ventilator parameters in order to adequately ventilate the patient and prevent injury, such as volutrauma, barotrauma. Adequate ventilation can prevent postoperative respiratory complications and is attained by a logical combination of tidal volume, respiratory rate, and PEEP. It is well known that airway pressure can be increased using an increased tidal volume, increased respiratory rate, and PEEP. In our institution, two rational ventilation options may be available, both guided by end-tidal carbon dioxide concentration in expired air ($ETCO_2$) and blood gases and by maintaining airway pressure at $<$30–35 cmH_2O. The first option includes standard tidal volume (8–10 ml/kg, ideal body weight), respiratory rate 10–12 min, and moderate PEEP (5–8 cmH_2O). The second option is based on low tidal volume (6–8 ml/kg), respiratory rate 12–18 min, and PEEP (8–10 cmH_2O). Pelosi et al. [65] recommended tidal volume of 6–10 ml/kg based on ideal body weight, increased respiratory rate to maintain physiological partial pressure of carbon dioxide in arterial blood ($PaCO_2$), and a recruitment maneuver (35–55 cmH_2O for 6 s), followed by

PEEP application of 10 cmH_2O. The anesthesiologist must choose case by case how to ventilate the patient, taking care to minimize intraoperative (ventilator-induced injury by "aggressive ventilation") and postoperative (atelectasis by hypoventilation) respiratory complications. Neuromuscular blockade must be fully reversed before extubation. Muscle relaxant monitoring by nerve stimulation or using clinically aspects (muscular strength, following commands, lifting the head for 5 s) can give reliable information about safety during extubation. After extubation, CPAP or a pressure support mask should be available and, if necessary, delivered to the patient. These maneuvers may ameliorate oxygenation, increase functional residual capacity, and improve respiratory performance.

Fluid therapy

During surgery, the opening of the cavities makes evaporation possible. This explains temperature and fluid loss. Major surgery is also associated with extravasations and third-space loss. Obese patients undergoing bariatric or nonbariatric surgery may have protracted volume in the preoperative period as a result of preoperative fasting, forced urine output induced by diabetes, and antihypertensive drugs (e.g., diuretics). These problems are the reasons for postoperative renal failure. The predisposing factors are weight loss, BMI >50 kg/m^2, prolonged surgery, pre-existent renal disease, and intraoperative hypotension [66]. Fluid requirements may be greater than predicted, and in even a relatively short (2- to 3-h case), 4–5 l of crystalloid fluid may be needed to prevent acute tubular necrosis in the kidneys.

Role of regional anesthesia in obese individuals

Regional anesthesia offers many advantages to obese individuals undergoing to surgery. These include no airway manipulation, no general anesthetic drugs, no cardiorespiratory depression, and effective control of postoperative pain. Several studies [66–68], however, found that obesity makes regional anesthesia difficult. Hidden anatomic landmarks, difficulty in palpating bony landmarks or indentifying the midline, and the relatively short needle are possible causes [69]. Success rate can be improved by using ultrasound [70, 71]. Another feature of spinal anesthesia in obese patients is a tendency for cephalic spread of local anesthetic, more so than in a nonobese patient [68]. This phenomenon can be explained by smaller cerebrospinal fluid volume [69], allowing the anesthesiologist to reduce the local anesthetic dose. The majority of studies are performed in pregnant women, and data are controversial in the nonpregnant obese patient. So the recommendation to use a low dose remains controversial [72], carrying the risk of block failure and the need for general anesthesia during the surgical procedure [73].

Postsurgery complications

Obese patients are prone to respiratory complications after extubation. These complications vary from reintubation and MV to hypoxemia and atelectasis. Therefore, the patient's trachea must be extubated when fully recovery of neuromuscular activity is present. Respiratory physiotherapy is an important step in preventing hypoxemia, atelectasis, and pneumonia. Respiratory physiotherapy is attained by encouraging the patient to take deep breaths and to cough. These exercises cannot be achieved without aggressive pain therapy. Adequate pain therapy controls pain, prevents respiratory complication, and reduces thromboembolic events. The main goal is to adequately control pain and avoid oversedation. Several pain therapy regimes are recommended, but a multimodal analgesic strategy using the combination of opiate-sparing patient-controlled analgesia with epidural analgesia seems to be the most preferred technique [74].

Thromboembolic events can be prevented using anticoagulants in the preoperative period. The selected anticoagulant agent is a protocol matter. Stress ulcer prophylaxis seems to be reasonable and effective, especially if a gastric bypass is to be performed. If the patient rests immobilized for a long period, pressure ulcers may occur in several parts of the body. Activating and periodically rotating the patient can be effective measures to prevent this complication. Surgery-related complications are bleeding, infection, perforation, anastomotic leaks, dehydration, peritonitis, pneumonia, DVT, malnutrition, vitamin K and B_{12} deficiency, and polyneuropathies.

Conclusions

The obese patient presents a great challenge to the anesthesiologist, who must deal with obesity-induced comorbidities and unique anesthetic considerations such as airway management, different drug dosage regimens, difficulties in monitoring and vascular access, respiratory and cardiac complications, and patient positioning.

Conflict of interest None.

References

1. Selassie M, Sinha A. The epidemiology and etiology of obesity: a global challenge. Best Pract Res Clin Anesthesiol. 2011; 25:1–9.
2. Ogden C, Carroll M, Curtin L, McDowell M, Tabak C, Flegal K. Prevalence of overweight and obesity in the United States, 1999–2004. JAMA. 2006;295(13):1549–55.

3. Flegal K, Carroll M, Ogden C, Curtin L. Prevalence and trends in obesity among US Adults, 1999–2008. JAMA. 2010;303(3): 235–41.
4. Berghöfer A, Pischon T, Reinhold T, Apovian C, Sharma A, Willich S. Obesity prevalence from a European perspective: a systematic review. BMC Public Health. 2008;8:200.
5. Stevens J. Ethnic-specific cutpoints for obesity vs country-specific guidelines for action. Int J Obes. 2003;27(3):287–8.
6. Calle E, Thun M, Petrelli J, Rodriguez C, Heath C. Body-mass index and mortality in a prospective cohort of U.S. adults. N Engl J Med. 1999;341(15):1097–105.
7. Dindo D, Muller M, Weber M, Clavien P. Obesity in general elective surgery. Lancet. 2003;361(9374):2032–5.
8. Courcoulas A, Schuchert M, Gatti G, Luketich J. The relationship of surgeon and hospital volume to outcome after gastric bypass surgery in Pennsylvania: a 3-year summary. Surgery. 2003; 134(4):613–21.
9. Adams J, Murphy P. Obesity in anesthesia and intensive care. Br J Anaesth. 2000;85:91–108.
10. Murphy P. Obesity. In: Hemmings H, Hopkins P, editors. Foundations of anaesthesia, basic and clinical sciences. London: Mosby; 2000. p. 703–11.
11. Westerly B, Dabbagh O. Morbidity and mortality characteristics of morbidly obese patients admitted to hospital and intensive care units. J Crit Care. 2011;26:180–5.
12. Lotia SH, Bellamy M. Anaesthesia and morbid obesity. Contin Educ Anaesth Crit Care. 2008;8(5):151–6.
13. Elamin EM. Nutritional care of the obese intensive care unit patient. Curr Opin Crit Care. 2005;11:300.
14. Poirier P, Giles TH, Bray G, Hong Y. Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss: an update of the 1997 American Heart Association scientific statement on obesity and heart disease from the obesity committee of the council on nutrition, physical activity, and metabolism. Circulation. 2006;113:898–918.
15. Poirier P, Lemieux I, Mauriege P, Dewailly E, Blanchet C, Bergeron J, Despres J. Impact of waist circumference on the relationship between blood pressure and insulin: the Quebec Health Survey. Hypertension. 2005;45:363–7.
16. Muller D, Elahi D, Pratley R, Tobin J, Andres R. An epidemiological test of the hyperinsulinemia-hypertension hypothesis. J Clin Endocrinol Metab. 1993;76:544–8.
17. Backman L, Freyschuss U, Hallbert D. Cardiovascular function in extreme obesity. Acta Med Scand. 1983;149:437–9.
18. Pontiroli A, Pizzocri P, Saibene A, Girola A, Koprivec D, Fragasso G. Left ventricular hypertrophy and QT interval in obesity and in hypertension: effects of weight loss and of normalisation of blood pressure. Int J Obes. 2004;28:1118–23.
19. Kenchaiah S, Evans J, Levy D, Wilson P, Benjamin E, Larson M, Kannel W, Vasan R. Obesity and the risk of heart failure. N Engl J Med. 2002;347:305–13.
20. Horwich T, Fonarow G, Hamilton M, MacLellan W, Woo M, Tilisch J. The relationship between obesity and mortality in patients with heart failure. J Am Coll Cardiol. 2001;38(3): 789–95.
21. Lazarus R, Sparrow D, Weiss ST. Effects of obesity and fat distribution on ventilatory function: the normative aging study. Chest. 1997;111(89):1–898.
22. American Society of Anesthesiologists Task Force. Practice guidelines for the peri-operative management of patients with obstructive sleep apnoea. A report of the American Society of Anesthesiologists Task Force. Anesthesiology. 2006;104: 1081–93.
23. Altermatt F, Muñoz H, Delfino A, Cortínez LI. Pre-oxygenation in the obese patient: effects of position on tolerance to apnoea. Br J Anaesth. 2005;95:706–9.
24. den Herder C, Schmeck J, Appelboom D, de Vries N. Risks of general anaesthesia in people with obstructive sleep apnoea. BMJ. 2004;329:955.
25. Benumof J. Obstructive sleep apnea in the adult obese patients: implication for airway management. Anesthesiol Clin N Am. 2002;20(4):789–811.
26. Vgontzas AN, Tan TL, Bixler EO, Martin LF, Shubert D, Kales A. Sleep apnea and sleep disruption in obese patients. Arch Intern Med. 1994;154:1705–11.
27. Frey WC, Pilcher J. Obstructive sleep-related breathing disorders in patients evaluated for bariatric surgery. Obes Surg. 2003;13: 676–83.
28. O'Donnell C, Schaub C, Haines A, Berkovitz D, Tankersley C, Schwartz A, Smith Ph. Leptin prevents respiratory depression in obesity. Am J Respir Crit Care Med. 1999;159:1477–84.
29. Brodsky J, Lemmens H, Brock-Utne J, Vierra M, Saidman L. Morbid obesity and tracheal intubation. Anesth Analg. 2002; 94(3):732–6.
30. Juvin P, Lavaut E, Dupont H, Lefevre P, Demetriou M, Domoulin J, Desmont J. Difficult tracheal intubation is more common in obese than in lean patients. Anesth Analg. 2003;97(2):595–600.
31. Domi R. The best prediction test of difficult intubation. J Anaesth Clin Pharmacol. 2010;26(2):193–6.
32. Lundstrøm LH, Moller A, Rosenstock Ch, Astrup G, Wetterslev J. High body mass index is a weak predictor for difficult and failed tracheal intubation: a cohort study of 91,332 consecutive patients scheduled for direct laryngoscopy registered in the Danish anesthesia database. Anesthesiology. 2009;110(2): 266–74.
33. Williamson JA, Webb RK, Szekely S, Gillies E, Dreosti A. The Australian Incident Monitor Study. Difficult intubation: an analysis of 2000 incident reports. Anaesth Intensive Care. 1993;21: 602–7.
34. Marchesini G, Moscatiello S, Di Domizio S, Forlani G. Obesity-associated liver disease. J Clin Endocrinol Metab. 2008;93(11 Suppl 1):S74–80.
35. Friedenberg F, Xanthopoulos M, Foster G, Richter J. The association between gastroesophageal reflux disease and obesity. Am J Gastroenterol. 2008;103(8):2111–22.
36. Hansson P, Eriksson H, Welin L, Svardsudd K, Vilhelmsen L. Smoking and abdominal obesity: risk factors for venous thromboembolism among middle-aged men: 'the study of men born in 1913'. Arch Intern Med. 1999;159:1886–90.
37. Goldhaber S, Grodstein F, Stampfer M, Manson J, Golditz G, Speizer F, Willett W, Hennekens Ch. A prospective study of risk factors for pulmonary embolism in women. JAMA. 1997;277(8): 642–5.
38. Blaszyk H, Bjornsson J. Factor V Leiden and morbid obesity in fatal postoperative pulmonary embolism. Arch Surg. 2000;135: 1410–3.
39. Kurth T, Gaziano J, Berger K, Kase C, Rexrode K, Cook N, Buring J, Manson J. Body mass index and the risk of stroke in men. Arch Intern Med. 2002;162:2557–62.
40. Lopez-Jiminez F, Bhatia S, Collazo-Clavell ML, Sarr M, Somers V. Safety and efficacy of bariatric surgery in patients with coronary artery disease. Mayo Clin Proc. 2005;80(9):1157–62.
41. Patis S, Schneider H, Schwartz A, Smith P. Adult obstructive sleep apnea. Chest. 2007;132:325–77.
42. Hillman DR, Loadsman JA, Platt PR, Eastwood P. Obstructive sleep apnea and anaesthesia. Sleep Med Rev. 2004;8(6): 459–71.
43. Beevers G, Lip GY, O'Brien E. ABC of hypertension. Blood pressure measurement. Part I-sphygmomanometry: factors common to all techniques. BMJ. 2001;322:981.
44. Miller AH, Roth BA, Mills TJ, Woody J, Longmoor Ch, Foster B. Ultrasound guidance versus the landmark technique for the

placement of central venous catheters in the emergency department. Acad Emerg Med. 2002;9(8):800–5.
45. Gann M Jr, Sardi A. Improved results using ultrasound guidance for central venous access. Am Surg. 2003;69:1104.
46. Dhonneur G, Combes X, Leroux B, Duvaldestin P. Postoperative obstructive apnea. Anesth Analg. 1999;89:762–7.
47. Ezri T, Gewurtz G, Sessler DI, Medalion P, Szmuk P, Hagbeg C, Susmailan S. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia. 2003;58:1111–4.
48. Shiga T, Wajima Z, Inoue T. Predicting difficult intubation. Anesthesiology. 2006;104:618–9.
49. Collins JS, Lemmens HJ, Brodsky JB, Brock-Utne J, Levitan R. Laryngoscopy and morbid obesity: a comparison of the ''sniff'' and ''ramped'' positions. Obes Surg. 2004;14(9):1171–5.
50. Curet M. Special problems in laparoscopic surgery: previous abdominal surgery, obesity, and pregnancy. Surg Clin N Am. 2000;80(4):1093–110.
51. McEwen DR. Intraoperative positioning of surgical patients. AORN J. 1996;63(6):1059–63.
52. Leykin Y, Miotto L, Pellis T. Pharmacokinetic consideration in the obese. Best Pract Res Clin Anesthesiol. 2011;25:27–36.
53. Ingrande J, Brodsky J, Lemmens H. Lean body weight scalar for the anesthetic induction dose of propofol in morbidly obese subjects. Anesth Analg. 2011;113(1):57–62.
54. Ingrande J, Lemmens H. Dose adjustment of anaesthetics in the morbidly obese. Br J Anaesth. 2010;105(Suppl 1):i16–23.
55. Egan TD, Huizinga B, Gupta SK, Jaarsma R, Sperry R, Yee J, Muir K. Remifentanil pharmacokinetics in obese versus lean patients. Anesthesiology. 1998;89(3):562–73.
56. De Baerdemaeker LEC, Jacobs S, Den Blauwen NMM. Postoperative results after desflurane or sevoflurane combined with remifentanil in morbidly obese patients. Obes Surg. 2007;16(6): 728–33.
57. Casati A, Putzu M. Anesthesia in the obese patient: pharmacokinetic consideration. J Clin Anesth. 2005;17(2):134–45.
58. Coussa M, Proietti S, Schnyder P, Frascarolo Ph, Suter M, Spahn D, Magnusson L. Prevention of atelectasis formation during the induction of general anesthesia in morbidly obese patients. Anesth Analg. 2004;98:1491–5.
59. Gander S, Frascarolo P, Suter M, Spahn D, Magnusson L. Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. Anesth Analg. 2005;100(2):580–4.
60. Dixon BJ, Dixon JB, Carden JR. Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study. Anesthesiology. 2005;102:1110–5.
61. The Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. NEJM. 2000;342:1301–8.
62. O'Brien JM, Welsh CH, Fish RH, Ancukiewicz M, Kramer AM. Excess body weight is not independently associated with outcome in mechanically ventilated patients with acute lung injury. Ann Intern Med. 2004;140:338–45.
63. Pelosi P, Ravagnan I, Giurati G, Panigada M, Bottino N, Tredici S, Eccher G, Gattinoni L. Positive end expiratory pressure improves respiratory function in obese but no in normal subjects during anesthesia and paralysis. Anesthesiology. 1999;91: 1221–31.
64. Perilli V, Sollazzi L, Modesti C, Annetta M, Sacco T, Bocci M, Tacchino R, Proietti R. Comparison of positive end-expiratory pressure with reverse Trendelenburg position in morbidly obese patients undergoing bariatric surgery: effects on hemodynamics and pulmonary gas exchange. Obes Surg. 2003;13:605–9.
65. Pelosi P, Gregoretti C. Perioperative management of obese patients. Best Pract Res Clin Anaesthesiol. 2010;24(2):211–25.
66. Sharma SK, McCauley J, Cottam D, Mattar S, Holover S, Dallal R, Lord J, Danner O, Ramanathan R, Eid G, Schauer Ph. Acute changes in renal function after laparoscopic gastric surgery for morbid obesity. Surg Obes Relat Dis. 2006;3:389–92.
67. Cotter JT, Nielsen KC, Guller U, Steele S, Klein S. Increased body mass index and ASA physical status IV are risk factors for block failure in ambulatory surgery: an analysis of 9,342 blocks. Can J Anaesth. 2004;51(8):810–6.
68. Taivainen T, Tuominen M, Rosenberg PH. Influence of obesity on the spread of spinal analgesia after injection of plain 0.5% bupivacaine at the L3-4 or L4-5 interspace. Br J Anaesth. 1990;64:542–6.
69. Ingrande J, Brodsky J, Lemmens H. Regional anesthesia and obesity. Curr Opin Anaesthesiol. 2009;22:683–6.
70. Grau T, Bartusseck E, Conradi R, Martin E, Motsch J. Ultrasound imaging improves learning curves in obstetric epidural anesthesia: a preliminary study. Can J Anaesth. 2003;50(10):1047–50.
71. Wallace DH, Currie JM, Gilstrap LC, Santos R. Indirect sonographic guidance for epidural anesthesia in obese pregnant patients. Reg Anesth. 1992;17:233–6.
72. Reyes M, Pan P. Very low-dose spinal anesthesia for cesarean section in a morbidly obese preeclamptic patient and its potential implications. Int J Obes Anesth. 2004;13(2):99–102.
73. Brodsky J, Mariano E. Regional anaesthesia in the obese patient: lost landmarks and evolving ultrasound guidance. Best Pract Res Clin Anesthesiol. 2011;25:61–72.
74. Schumann R, Jones S, Cooper B, Kelley S, Bosch M, Ortiz V, Connor K, Kaufman M, Harvey A, Carr D. Update on best practice recommendations for anesthetic perioperative care and pain management in weight loss surgery, 2004-2007. Obesity. 2009;17:889–94.