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# How can I manage anaesthesia in obese patients?

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## ABSTRACT

The obese patient is at risk of perioperative complications including difficult airway access (intubation, difficult or impossible ventilation), and postextubation acute respiratory failure due to the formation of atelectases or to airway obstruction. The association of obstructive sleep apnoea syndrome (OSA) with obesity is very common, and induces a high risk of per and postoperative complications. Preoperative OSA screening is crucial in the obese patient, as well as its specific management: use of continuous positive pre-, per- and postoperative pressure. For any obese patient, the implementation of difficult intubation protocols and the use of protective ventilation (low tidal volume 6–8 mL/kg of ideal body weight, moderate positive end-expiratory pressure of 10 cmH<sub>2</sub>O, recruitment manoeuvres in absence of contra-indications), with morphine sparing and semi-seated positioning as much as possible are recommended, associated with a close postoperative monitoring. The dosage of anaesthetic drugs is usually based on the ideal body weight or the adjusted body weight and then titrated, except for succinylcholine that is dosed according to the total body weight. Monitoring of neuromuscular blockers should be used where appropriate, as well as monitoring of the depth of anaesthesia, especially when total intravenous anaesthesia is used in association with neuromuscular blockers. The occurrence of intraoperative awareness is indeed more frequent in the obese patient than in the non-obese patient. Appropriate prophylaxis against venous thromboembolism and early mobilisation are recommended, if possible included in an early rehabilitation protocol, to further reduce postoperative complications.

Keywords:  
Anaesthesia  
Obese  
Obesity  
Airway  
Preoxygenation

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## 1. Introduction

During the last thirty years, a significant increase in obesity prevalence has been observed around the world [1]. Overweight and obesity are defined as abnormal or excessive fat accumulation presenting an increased health risk. A crude population measure of obesity is the body mass index (BMI), a person's weight (in kilograms) divided by the square of his or her height (in meters), as defined by the World Health Organization (WHO) [2]. A person with a BMI of 30 or more is considered obese, of 40 or more morbidly obese, of 50 or more super-obese and of 60 or more super-super-obese [3,4]. A person with a BMI equal to or more than 25 is considered to be overweight [5]. In 2016, 39% of women and 39% of men aged 18 and over were overweight and 11% of men and 15% of women were obese [2].

Obese patients are at higher risk of perioperative complications than non-obese patients, mainly those related to the respiratory function [6]. Comorbidities and type of surgery are crucial for assessing the perioperative risk of these patients [7]. Preoperative SpO<sub>2</sub>, at least one preoperative respiratory symptom, preoperative chronic liver disease, history of congestive heart failure, open intrathoracic or upper abdominal surgery, surgical procedure lasting at least 2 h, and emergency surgery were associated with postoperative respiratory failure [8]. Intraoperatively, colloid administration and blood transfusion were also found to be associated with postoperative pneumonia [9]. Super-obese and super-super-obese patients are high-risk surgical patients with reported higher perioperative mortality and morbidity compared to overweight and obese patients [4,10].

Airway management can be challenging, with increased incidence of difficult mask ventilation and intubation [11,12]. The use of analgesic and sedative drugs in the immediate postoperative period increases the risk of respiratory depression [13]. Careful preparation, preoperative risk assessment, adequate anaesthetic management, blood pressure and glycaemic control, strict prevention of thromboembolic events, and effective control of postoperative pain may help reduce the risk associated with surgery in obese patients.

There are specific complications due to pathophysiological state and a specific management of obese patients [14,15]. Two types of surgery should be considered in obese patients: bariatric and non-bariatric surgeries, with different outcomes and specificities [6]. The objective of this review is to present the perioperative peculiarities of anaesthesia of obese patients in order to offer optimised perioperative medical management, according to the type of surgery performed, bariatric or non-bariatric, aimed at reducing perioperative complications.

## 2. Pathophysiological consequences of obesity

### 2.1. Respiratory

In obese patients, intra-abdominal pressure is increased, and total lung capacity, vital capacity and functional residual capacity

(FRC) are decreased, which favours the formation of atelectases [16,17]. In addition, oxygen consumption and respiratory work are increased [18], which leads to a decrease in oxygenation [16]. During anaesthesia, decreased pulmonary compliance is responsible for an increase in transpulmonary pressure (difference between the alveolar pressure and the pleural pressure) [19]. This transpulmonary pressure must be differentiated from the transthoracic pressure (difference between pleural pressure and atmospheric pressure, due to compression of the thoracic cavity by the abdomen). Extra pressure, whether transpulmonary or transthoracic, leads to an increase in ventilation pressures [19], which can be associated with haemodynamic compromise. Prolonged increased transpulmonary pressures are associated with an increased rate of postoperative pulmonary complications [20].

Obesity predisposes to and potentiates obstructive sleep apnoea syndrome (OSA) [21,22]. Moreover, the atelectasis and lung volume reduction are more severe in obese patients than in non-obese patients and sustained for more than 24 h, even after minor surgery, causing hypoxemia during and after surgery [23]. Increased abdominal volume with reduction of pulmonary volumes including FRC participates to the higher incidence of atelectases in obese patients [12]. Obese patients are therefore at increased risk of postoperative respiratory complications, including Acute Respiratory Distress Syndrome (ARDS) [14,24,25].

### 2.2. Cardiovascular

Obesity causes high blood pressure, increases cardiac output and cardiac work, as well as the incidence of coronary heart disease and arrhythmia [26]. The risk of atrial fibrillation is 1.5 times greater in the obese patient than in the non-obese patient [27]. The occurrence of long QT is also more common in obese patients [28].

Moreover, obesity is a prothrombotic condition associated with the occurrence of myocardial infarction, stroke and venous thromboembolism [15,29]. Postoperative incidence of venous thrombosis is ten times higher in obese women than in non-obese women [30]. A hypercoagulable condition may persist for two months, necessitating prolonged postoperative prophylaxis of thromboembolic venous disease depending on the type of surgery and the patient's BMI [31].

### 2.3. Endocrine and metabolic systems

Patients with centrally dispensed or "android" fat are at higher perioperative risk than those with peripheral fat or "gynoid shape" [32].

Insulin resistance and diabetes are common in obese patients [33]. Poor glycaemic control in the perioperative period is associated with increased morbidity [34]. In bariatric surgery, bypass gastric surgery results in a neurohumoral response, responsible for a rapid and significant reduction in insulin requirements, which begins immediately after surgery. In this type of patients, reintroduction of anti-diabetic drugs should be

careful and frequent blood glucose control should be performed postoperatively [35].

### 3. The prevention of perioperative complications

The experience of the anaesthetist and the surgeon with this type of patient is important, and an experienced team should be mandatory in obese patients at very high perioperative risk.

The weight limit for operating tables must be checked before any bariatric surgery, and appropriate tables installed. The installation of the bariatric patient is very important, in a room spacious enough to allow for unencumbered transfer of the morbidly obese patient to and from the operating theatre table. The supine position with the legs abducted on straight leg boards is largely used (“beach chair position”).

Table 1 presents the main perioperative complications in obese patients and some key points to prevent them.

#### 3.1. Respiratory management

##### 3.1.1. Preoperative preparation

Whatever the type of surgery, and more particularly in bariatric surgery, a preoperative regimen may improve operating conditions [36]. A reasonable weight loss is recommended to reduce perioperative respiratory and cardiovascular complications.

Smoking cessation should be encouraged preoperatively. It appears that a smoking abstinence period of 6 to 8 weeks reduces the risk of postoperative respiratory complications to that of non-smokers [37]. However, even shorter delays are still significant to minimise the risks associated with hyper reactivity and lack of

tissue oxygenation by decreasing carboxyhaemoglobin. As a consequence, it is advised to stop smoking preoperatively, whatever the delay [37].

In the case of associated OSA, an observational study reports a decrease in postoperative severe complications (i.e., cardiac events, respiratory complications) when applying CPAP preoperatively compared to the absence of CPAP [38]. Preoperative initiation of CPAP should therefore be considered, especially if OSA is severe. Preoperative use of mandibular advancement devices is advised when it is effective.

The identification of an already diagnosed OSA or the screening for an OSA not yet diagnosed is the main corner of the management of the obese patient. Comorbidities associated with increased incidence of OSA should be sought [39], such as high blood pressure [40], a history of stroke [41], of myocardial infarction [42], diabetes [43] or facial dysmorphism [44]. Any complication that has occurred during a previous procedure, such as difficult intubation or postoperative respiratory distress, should also be sought. Snoring, episodes of nocturnal apnoea, frequent awakenings during sleep (for example, vocalisation, changes of position, extremity movements), morning headaches and daytime sleepiness will suggest an OSA. Epworth score [45] assesses the propensity to doze in 8 different situations of everyday life. A score greater than or equal to 15 indicates excessive daytime sleepiness.

STOP-BANG score [46] is more and more used (Table 2) and validated in the obese patient [46]. The reference exam to confirm the diagnosis is polysomnography, or respiratory polygraphy. OSA is defined by the combination of daytime sleepiness and polysomnographic criteria (apnoea hypopnea index [AHI]  $\geq 5$ ). The severity of OSA depends on clinical symptoms and AHI:

**Table 1**  
Prevention of perioperative complications in the obese patient.

Complications	Prevention
<i>Respiratory</i>	
Difficult mask ventilation	Loco-regional anaesthesia if possible
Difficult intubation	Rapid sequence induction if gastro-oesophageal reflux disease
Per- and postoperative atelectases	Preoxygenation with NIV $\pm$ HFNO PEEP and alveolar recruitment manoeuvres during invasive mechanical ventilation Postoperative (prophylactic) NIV if high risk of respiratory complications Early mobilisation Active respiratory physiotherapy
<i>Cardiovascular</i>	
Difficult perfusion	Central venous access, ultrasound++
Difficult monitoring (blood pressure+++)	Appropriate blood pressure cuff or invasive monitoring
Heart disease, pulmonary arterial hypertension	Specific monitoring, right pulmonary catheterisation, heart ultrasound
Excessive fluid loading	Fluid restriction, ideal body weight calculation for fluid loading
<i>Related to anaesthetic drugs</i>	
Prolonged action of anaesthetic drugs (opioid+++)	Balanced anaesthesia, opioid sparing
Residual use of neuromuscular blockers	Fast-acting opioid Neuromuscular blockers based on ideal body weight
<i>Pneumoperitoneum</i>	
Cardiopulmonary repercussion	Intraperitoneal pressure < 15 mmHg
Perioperative renal dysfunction	No excessive fluid loading
<i>Position, neuropathy</i>	
	Appropriate material Checking points of support after mobilisation Training of the health care team
<i>Thromboembolic risk</i>	
	Mechanic means (compression stockings, intermittent compression++) Prophylactic anticoagulation Early postoperative mobilisation
<i>Postoperative analgesia</i>	
Opioid-induced respiratory depression	Loco-regional analgesia Continuous monitoring, pain assessment++ No continuous flow if patient-controlled morphine pump Non-opioid analgesia Standardised protocols

NIV: non-invasive ventilation; PEEP: positive end-expiratory pressure.

**Table 2**  
STOP-BANG score.

S	Snoring
T	Tired
O	Observed apnoea
P	Pressure (high blood pressure treated or untreated)
B	Body mass index > 35 kg/m <sup>2</sup>
A	Age > 50 years old
N	Neck circumference > 40 cm
G	Gender male
STOP-BANG (one point by item): clinical diagnosis of obstructive apnoea syndrome if $\geq 3$	

- clinical symptoms: the severity of daytime sleepiness is assessed on the impact it has on the activities of social or professional life: mild (low impact), moderate (moderate repercussion), severe (significant disruption);
- an AHI from 5 to 15 events/h define a mild OSA, 15 to 29 a moderate OSA and  $\geq 30$  a severe OSA [47].

Continuous positive airway pressure (CPAP) equipment is indicated in patients with severe OSA (AHI greater than 30 obstructive events/h). For lower IAH values, CPAP at night will be indicated in case of severe cardiovascular comorbidity. CPAP is proposed as first-line in these indications. In order to decrease daytime sleepiness, treatment may also be offered to patients with OSA with an AHI less than 30 and with no associated serious cardiovascular comorbidity. Mandibular Advancement Orthosis is recommended as first-line therapy for this indication.

Regardless of the association or not with an OSA, the obesity-hypoventilation syndrome is defined by:

- chronic alveolar hypoventilation: PaCO<sub>2</sub> > 45 mmHg (PaO<sub>2</sub> < 70 mmHg);
- obesity (BMI  $\geq 30$  kg/m<sup>2</sup>);
- the absence of associated respiratory disease.

In the case of associated OSA and moderate hypercapnia between 45 and 55 mmHg, CPAP equipment will be offered as first-line, followed by non-invasive ventilation (NIV) equipment in case of failure, allowing ventilation at two pressure levels. In case of a history of respiratory decompensation with acute hypercapnic respiratory insufficiency, hypercapnia greater than 55 mmHg and/or in the absence of associated OSA, a NIV device will be proposed.

Obesity and Chronic Obstructive Pulmonary Disease (COPD) are often associated. Asthma is also more common in obese patients. In addition, obesity by itself can generate an obstructive syndrome [48]. The anaesthetist should be aware that a bronchospasm is likely to occur per and postoperatively. OSA and obesity, and a fortiori the combination of both, are risk factors for difficult intubation [12]. Any intubation in an obese patient should be considered potentially difficult, and adequate preparation following a difficult intubation algorithm should be mandatory.

**3.1.1.1. Airway management.** OSA associated with obesity is a risk factor for difficult ventilation [49]. Patients with a beard should ideally shave to decrease the risk of poor ventilation. Similarly, tracheal intubation is more difficult in patients with OSA, reaching 15 to 20% (*versus* 2 to 5% in the general population), especially if OSA is severe [50,51]. Obesity probably contributes to the difficulty of intubation in patients with OSA. A recent study [12] showed an increase in the incidence of difficult intubation in obese patients. Moreover, in this same study [12], a high Mallampati score, a reduction in cervical mobility and the presence of OSA have been associated with difficult intubation in obese patients, suggesting the potential involvement of specific anatomical factors in obese patients predisposing to difficult intubation [52]. Both difficult

mask ventilation and difficult tracheal intubation are risk factors for hypoxemia at induction of general anaesthesia [53], suggesting that techniques improving preoxygenation should be implemented in daily practice in obese patients.

Preoxygenation in spontaneous ventilation with a face mask is followed by rapid desaturation after induction in obese patients, despite a high-inspired oxygen fraction (FiO<sub>2</sub>) (3 min on average, sometimes less than 1 min in case of very severe obesity) [21,54]. It has also been shown [55] that the lung volume at the end of expiration was reduced by 69% after anaesthetic induction in the supine position. Five minutes of preoxygenation in NIV (inspiratory support [AI] + positive expiratory pressure [PEP]) allowed to obtain an expired fraction of oxygen (FeO<sub>2</sub>) > 90% more rapidly [56]. In another study [57], the use of NIV limited the decrease of lung volume and improved oxygenation compared to a conventional preoxygenation with the face I mask.

High-Flow Nasal Cannula Oxygen Therapy (HFNO), which provides a high-flow rate, heated and humidified air through a nasal cannula at a 100% fraction of inspired oxygen (FiO<sub>2</sub>) and a maximum flow rate of 60 L/min, can allow the passage of the orotracheal tube through the mouth. In patients with acute hypoxemic respiratory failure, several mechanisms for improving oxygenation with HFNO have recently been identified. [58]: reduction of patient effort and minute ventilation required to achieve a physiological rate of arterial carbon dioxide, increase in end-expiratory lung volume, improvement of dynamic compliance, positive transpulmonary pressure and homogenisation of ventilation. Apnoea oxygenation is a physiological phenomenon in which the difference between the alveolar rates of oxygen removal and carbon dioxide excretion generates a negative pressure gradient of up to 20 cmH<sub>2</sub>O. This negative pressure gradient allows the entry of oxygen into the lungs, provided there is airway permeability between the lungs and the atmosphere. A first study [59] evaluated the influence of nasal oxygen administration on the duration of peripheral oxygen saturation (SpO<sub>2</sub>)  $\geq 95\%$  in simulated difficult laryngoscopy in obese patients. Nasal administration of O<sub>2</sub> was associated with a significant increase in the frequency and duration of SpO<sub>2</sub>  $\geq 95\%$  and a higher minimal SpO<sub>2</sub> in prolonged laryngoscopy in obese patients. Another observational prospective study [60] focused on the apnoea time of 25 patients with difficult planned intubation and undergoing general anaesthesia for hypopharyngeal or laryngotracheal surgery. HFNO was administered continuously, for preoxygenation and continued after intravenous induction of anaesthesia and neuromuscular blockade, until airway safety was ensured. Twenty-five patients were included, including 12 obese patients. The median apnoea time was 14 (5–65) min. No arterial oxygen desaturation was observed during the apnoea period. However, apnoea oxygenation has to be differentiated from preoxygenation. If apnoea oxygenation using HFNO can help to decrease the occurrence of low oxygen saturation during the apnoea, HFNO should not be used as a method of preoxygenation in the obese patient. In a recent single centre study [61], preoxygenation with HFNO in obese patients provided lower end-tidal oxygen concentration (EtO<sub>2</sub>) after intubation and a higher rate of desaturation < 95%, compared to preoxygenation with NIV.

After prolonged preoxygenation, positive pressure and semi-sitting position [62,63], the anaesthesiologist has to decide whether to carry out a rapid sequence induction or not. This consists in the administration of a hypnotic and a neuromuscular blocker of rapid onset action, allowing to not ventilate the patient before intubation. In obese patients, gastroesophageal reflux is common, with hypotonia of the lower oesophageal sphincter [64]. Although bronchial inhalation during the induction of anaesthesia is rare, it is an important cause of anaesthesia-related mortality. Even if this induction technique is appropriate in obese

patients with symptomatic gastroesophageal reflux and/or full stomach, the benefit/risk balance of the rapid sequence induction should be evaluated in the absence of other risk factors for added inhalation. In an unscheduled situation, the rapid sequence induction will be almost systematic. Intubation awakened with a fiberoptic should be considered if there is a very high risk of difficult intubation and mask ventilation [65]. The use of a videolaryngoscope is the method of choice in case of difficult intubation of obese patients [65,66], predicted (when the mouth opening is more than 2 cm to allow the videolaryngoscope introduction) or unpredicted. The insertion of a laryngeal mask is strongly recommended in case of difficult intubation and/or difficult mask ventilation [65].

### 3.1.2. Setting of ventilatory parameters

The French [20], multicentre, randomised, double blind IMPROVE study, compared an “optimised” ventilation strategy called “protective ventilation” (tidal volume TV 6–8 mL/kg IBW, PEEP 6–8 cmH<sub>2</sub>O, systematic alveolar recruitment manoeuvre every 30 min) to a traditional strategy called “non-protective ventilation” (TV 10–12 mL/kg IBW without PEEP or alveolar recruitment) in major abdominal surgery. Protective ventilation reduced the overall complication rate from 27.5 to 10.5% and reduced the length of hospital stay by 2 days. Patients with BMI  $\geq 35$  kg/m<sup>2</sup> were excluded. The results of this study nevertheless seem generalisable to any obese patient. In both obese and non-obese patients, the optimal TV seems to be between 6 and 8 mL/kg IBW by associating a PEEP to avoid atelectasis by alveolar closure (derecruitment). The setting of the VT should be guided by the size of the patient and not by measured weight. The easiest IBW calculation formula to remember is: IBW (in kg) = height (in cm) – 100 in men and height (in cm) – 110 for women. However, a recent study [67] showed that obese patients were often ventilated with a very high TV (> 10 mL/kg) peroperatively.

Respiratory rate should be increased in obese patients. In fact, the obese patient has a hyperproduction of CO<sub>2</sub>, secondary to high oxygen consumption (VO<sub>2</sub>), associated with an increase in respiratory work [68,69]. The ventilation settings can therefore be guided by repeated arterial blood gases. Capnography has limitation in obese patients, because of a greater expired CO<sub>2</sub>/arterial CO<sub>2</sub> gradient than in healthy subjects [19].

Obese patients are more sensitive to atelectasis and therefore to the absence of PEEP. In obese patients, gas exchange is improved by the application of a PEEP, as well as respiratory mechanics and alveolar recruitment (decrease of inspiratory resistance and improvement of compliance) [16,70].

However, when the alveoli have been collapsed, the isolated application of a PEEP alone will not reopen them, when recruitment manoeuvres will allow them to be reopened (recruitment). It is therefore recommended to apply at the beginning of the mechanical ventilation and during the whole ventilation period a PEEP of approximately 10 cmH<sub>2</sub>O, associated with a TV of 6 to 8 mL/kg of IBW [57,71] and regular recruitment manoeuvres [57]. Recruitment manoeuvre using bag squeezing should be avoided, as it was recently found to be associated with postoperative pulmonary complications [72].

However, all obese patients are not the same, and individual monitoring should be used whenever possible. In a recent study [73], an intraoperative mechanical ventilation strategy with a higher level of PEEP and alveolar recruitment manoeuvres, compared with a strategy with a lower level of PEEP, did not reduce postoperative pulmonary complications in non-selected obese patients. However, use of vasopressors was higher in the interventional group. Optimisation of fluid loading should always be checked before applying a strategy of “open lung”. Oesophageal pressure monitoring can also help PEEP titration in obese patients,

by setting the minimal PEEP allowing to obtain a positive transpulmonary pressure, in order to limit the occurrence of atelectases (PEEP level too low) or overdistension (PEEP level too high) [74]. Nevertheless, the haemodynamic effects of the application of high pressures (high PEEP and/or recruitment manoeuvres) should always be assessed: risk of decreased arterial oxygenation and hypotension due to repercussions on cardiac output [75]. Driving pressure (plateau pressure – PEEP) may not be an appropriated parameter in obese ARDS patients [76]. Further studies are needed in obese non-ARDS patients.

Some teams advocate the controlled pressure mode, as the decelerating flow would allow a better distribution of the airflow in the alveoli. However, the studies comparing the two ventilatory modes report contradictory data: the divergences can be explained by different criteria of judgment between the studies and methodological limits [77]. In practice, the advantages and disadvantages of each of both modes should be considered and the most appropriate ventilation mode should be used.

### 3.1.3. Extubation

If possible, extubation will be performed in a lateral or semi-sitting position, but not lying down. Extubation should be performed as soon as possible, avoiding prolonged mechanical ventilation [78]. If rocuronium was used during the surgery, antagonisation of rocuronium by suggamadex should be considered [79], as recently advised by the French recommendations about neuromuscular blockers use [80].

### 3.1.4. Postoperative oxygenation/ventilation

Oxygen supplementation should be administered continuously to all patients with OSA until they are able to maintain baseline oxygen saturation in ambient air. If possible, CPAP or NIV (with or without oxygen supplementation) can be used continuously in patients who use these modalities preoperatively, unless they are contraindicated by the surgical procedure. A randomised controlled trial [81] showed an improvement in ventilatory function when comparing postoperative CPAP to the absence of postoperative CPAP. Compliance with CPAP or NIV could be improved if patients bring their own equipment to the hospital. In the case of well-tolerated equipment and in the absence of other postoperative complications requiring monitoring in intensive care units, the patient may be admitted to a surgery ward. If possible, lying position should be avoided in patients with or at risk of OSA. In case of frequent and/or severe hypoxemia, initiation of CPAP or NIV sessions should be considered. The prophylactic application of a NIV after extubation could help to reduce the risk of acute respiratory failure by 16% and the length of stay. In addition, in obese hypercapnic patients [82], the use of postextubation NIV is associated with a decrease in mortality. In the case of major respiratory comorbidities, prophylactic NIV should be almost systematic in the recovery room and then in the intensive care unit.

Curative NIV can also be applied in case of acute respiratory failure to avoid intubation [83–85]. In obese patients with hypercapnia, higher levels of PEEP should be used over a longer period of time to reduce hypercapnia below 50 mmHg [14].

Postoperative HFNO has recently been investigated and compared with the use of postoperative NIV for cardiac and thoracic surgery, both preventive and curative, in a large population [86] including obese patients [87]. The non-inferiority of HFNO compared to the NIV was reached, suggesting effectiveness of postoperative HFNO therapy to prevent or avoid intubation.

### 3.1.5. Early rehabilitation

An improved rehabilitation protocol with early mobilisation after surgery, especially bariatric, is essential [88] to prevent respiratory complications. If possible, early removal of a urinary

catheter, infusions or other devices should be encouraged. Chest physiotherapy could be an important part of postoperative respiratory management improving respiratory functions, regulating arterial blood gases, increasing oxygen saturation, functional capacity and quality of life, and decreasing dyspnea levels [89].

### 3.2. Cardiovascular management

Morbidly obese patients often have very limited mobility and may be asymptomatic even when they have cardiovascular diseases. Physical examination is also difficult.

Obese patients should be evaluated in the same way as other patients, with a stress test, with appropriate equipment, in case of clinical suspicion of coronary heart disease.

Before the surgery, the preparation includes an adequate venous access, possibly using ultrasound guidance [90]. Monitoring of blood pressure can be particularly problematic in these patients. If the (blood pressure) cuff is too small, the blood pressure may be overestimated. The forearm can be used if the arm is too wide or cylindrical. In some cases, an arterial catheter may be necessary, and will also allow close monitoring of arterial blood gases.

Obese patients are particularly at risk for postoperative cardiovascular complications, including atrial fibrillation rhythm disorders [27]. Haemodynamic optimisation, especially avoiding overfilling or underfilling [91], by measurement of cardiac output by intra-oesophageal Doppler or transpulmonary thermodilution with monitoring of the pulse wave, could help to limit such perioperative complications.

Obesity is a risk factor for venous thromboembolism. Strategies to reduce the risk of venous thromboembolic complications include: early postoperative mobilisation, intermittent pneumatic compression, compression stockings and anticoagulant medications. Evidence of the effectiveness of simple compression stockings is limited. When used, it is essential that they be properly adjusted to prevent vascular occlusion. There is no argument in the literature for the routine use of vena cava filters in the obese population [92]. Oral anticoagulants such as rivaroxaban and dabigatran can be used for BMI  $\leq 40$  kg/m<sup>2</sup>. Dose adjustment is not recommended at this time. In case of BMI  $> 40$  kg/m<sup>2</sup>, monitoring by dosage is recommended. When using low molecular weight heparins (LMWH), several protocols of adjustment of doses exist [91]. The Association of Anaesthetists of Great Britain and Ireland Society for

Obesity and Bariatric Anaesthesia proposed the following recommendations [91]: If the patient is between 50 and 100 kg, 4000 IU/day of enoxaparin or equivalent could be used. If the patient is between 100 and 150 kg, 4000 IU twice a day of enoxaparin or equivalent could be considered, and if the patient is  $> 150$  kg, 6000 IU twice a day of enoxaparin or equivalent could be used [91]. The European guidelines on perioperative venous thromboembolism prophylaxis for obese patient surgery [93] recommend low-dose low molecular weight heparin (3000 to 4000 anti-Xa IU/12 h subcutaneously) for obese patients with a lower risk of venous thromboembolism, and a higher dose of low molecular weight heparin (4000 to 6000 anti-Xa IU/12 h subcutaneously) for obese patients with a higher risk of venous thromboembolism. They underlined that higher doses of anticoagulants could be proposed for obese patients with a BMI more than 40 kg/m<sup>2</sup>.

### 3.3. Metabolic-endocrine management

Screening for metabolic and nutritional abnormalities should be considered, especially in patients scheduled for bariatric surgery. The preoperative evaluation will focus on the presence of diabetes, anti-diabetic drugs and their possible perioperative delay. In general, these medications will not be stopped in case of outpatient surgery. In minor or major surgery, oral anti-diabetic medications will not be taken in the morning. Metformin will also not be taken the night before [94]. Vitamin and nutritional deficits can lead to postoperative polyneuropathy, known as acute neuropathy postgastric reduction, a nutritional disease characterised by postoperative vomiting, hyporeflexia and muscle weakness [95]. Special attention to the dosing and monitoring of the neuromuscular blockers is recommended in case of suspicion or diagnosis of neuropathy. Chronic vitamin K deficiency, in case of previous obesity surgery, may lead to coagulation abnormalities, necessitating the administration of vitamin K or fresh frozen plasma.

### 3.4. Gastro-intestinal management

The frequency of gastroesophageal reflux is strongly correlated with the increase in BMI [96]. Obesity is also associated with increased intra-abdominal pressure, gastric volumes, hiatal hernia, as well as decreased pH and fatty infiltration of the liver. An antacid premedication can be used before the procedure.

**Table 3**  
Dosages adjustments of some medications.

Weight	Definition	Antibiotics (initial dosing)	Others
Total body weight (real weight)	Real weight of the patient	Beta-lactam <sup>a</sup>	Succinylcholine
Ideal body weight	Lorentz formula. Men: ideal body weight (kg) = height (cm) - 100 - ((Height (cm) - 150)/4). Women: ideal body weight (kg) = Height (cm) - 100 - ((Height (cm) - 150)/2,5); = about height (cm) - 100 for men, height (cm) - 110 for women	Vancomycin (loading dose) Daptomycin (monitor CPK) Linezolid (standard doses 600 mg*2/j, continuous infusion may be useful, increasing doses according to CMI)	Neuromuscular blockers
Adjusted weight (closed to lean body weight)	Takes into account the increase in lean mass and in volume of distribution: ideal body weight + 0,4 (total body weight - ideal body weight)	Macrolides Beta-lactam <sup>a</sup>	Opioids Lidocaine
		Vancomycin (maintenance dose) Aminoglycoside Fluoroquinolones	Ketamine Propofol

CPK: creatinine phosphokinase. This table is given as an indication and remains to be completed and modified according to the practices of each centre and the new results reported in the literature. In all cases, during prolonged treatments, a dosage is recommended in order to better adapt the doses administered.

<sup>a</sup> The dose of beta-lactam will depend on the minimum inhibitory concentration (MIC) and toxicity. For amoxicillin and oxacillin, adjusted weight or actual weight may be used. For piperacillin-tazobactam, we can reach 20 to 24 g/24 h [115]. The doses of imipenem should theoretically be increased but the risk of toxicity including neurological will be increased, so it is better not to exceed 3 g/d, despite the risk of underdosing. For meropenem, the maximum dose of 2 g/8 h can be used. In prophylaxis, in patients over 100 kg and/or body mass index  $> 35$  kg/m<sup>2</sup>, even outside bariatric surgery, doses of beta-lactam should be twice those recommended for non-obese patients.

Patients with adjustable gastric rings (rings placed around the upper part of the stomach, defining a small pocket) have peculiarities. Indeed, these patients are at high risk of pulmonary inhalation during the induction of general anaesthesia due to a disorder of oesophageal motility and dilation above the ring. A rapid sequence induction should thus be used in this patient, and sedation without intubation in endoscopic procedures (gastroscopy, colonoscopy) should be avoided.

### 3.5. Drug management

#### 3.5.1. Antibioprophylaxis and antibiotherapy

The latest French Society of Anaesthesia and Intensive Care Medicine (SFAR) expert recommendations on perioperative antibiotic prophylaxis [97] have defined the antibiotic prophylaxis of the obese patient. In obese patients (patients over 100 kg and body mass index  $> 35 \text{ kg/m}^2$ ), doses of beta-lactams should be twice those recommended for non-obese patients. For vancomycin and gentamicin, doses of antibiotic prophylaxis are calculated on the actual weight.

When curative antibiotic therapy is required, the initial dosage will most often be based on actual weight or adjusted weight. The dose of aminoglycosides will be calculated on the adjusted weight. Then, repeated dosing is needed to adjust the dose of antibiotics performed. Table 3 presents the recommended dose adjustments for some antibiotics.

#### 3.5.2. Choice of anaesthetic technique

Loco-regional anaesthesia should always be preferred over general anaesthesia if possible. If general anaesthesia is required, the use of easily reversible and fast-acting drugs is the agent of choice for induction in obese patients.

There is little pharmacological data on anaesthetic drugs used routinely in obese patients (Table 3). Fortunately, many anaesthetic agents can be titrated.

The fasciculation associated with suxamethonium increase the consumption of oxygen and have shown a reduction in apnoea time without desaturation [98]. A dose of rocuronium based on total weight does not significantly shorten the duration of action, but significantly increases the duration of action [99]. The IBW is therefore recommended to adapt the doses of rocuronium. On the other hand, due to an increase in plasma cholinesterase activity, the total weight is appropriate for suxamethonium. The doses of neostigmine and sugammadex are related to the time and total dose of injected curare and will be titrated on efficacy. After rocuronium administration, sugammadex may provide faster recovery of neuromuscular function and prevent more postoperative residual curarisation in the morbidly obese patient compared to neostigmine [100]. Sugammadex is a hydrophilic molecule that distributes mainly in extracellular fluids and its effects should be only slightly affected by the volume of body fat [91,101]. Therefore, its dosage in morbidly obese patients should be based on weight lower than total body weight [91,102]. The recent recommendations are to use ideal body weight for dosing sugammadex [102] and then to monitor degree of neuromuscular blockade [80].

For maintenance of anaesthesia, short-acting anaesthetic agents should be used. Maintaining anaesthesia with propofol or halogenated agents should be initiated early after induction because of the increased risk of intraoperative awakening in the obese patient and thus intraoperative memory [103]. Airway reflexes are more quickly restored in case of desflurane anaesthesia compared to sevoflurane anaesthesia in obese patients [104].

Obese patients are very sensitive to the respiratory depressant effects of sedatives, opioids and inhaled anaesthetics. Benzodiazepines are to be avoided in these patients, even in premedication, because of their long half-life.

For opioids, the clinical effect is little related to plasma concentration [105]. The dose using the ideal weight is a starting point until the patient is awake and titration to effect is possible. For propofol, the Marsh and Schneider model is no longer reliable for patients over 140–150 kg [99]. This is why the pumps do not allow to enter weights  $> 150 \text{ kg}$  using the Marsh model, or a BMI  $> 35 \text{ kg/m}^2$  (female) and  $42 \text{ kg/m}^2$  (male) using the Schneider model.

### 3.6. Screening of bariatric complications

A rare but serious complication in the obese patient is rhabdomyolysis [106]. Predisposing risk factors, in addition to obesity, are: hypotension, immobility, long duration of surgery and insufficient fluid loading [107]. Rhabdomyolysis should be suspected in cases of deep postoperative pain, typically at the gluteal level. Blood creatinine phosphokinase (CPK) levels should be measured rapidly, and if increased, aggressive management may be required to prevent worsening of renal function [106].

Postoperative tachycardia may be the only sign of a postoperative surgical complication and should not be overlooked. The bleeding from the staple line and the early gastric fistula are the main complications of bariatric surgery.

#### 3.6.1.1. Postoperative analgesia

Loco-regional anaesthesia techniques should be considered to reduce or eliminate the use of opioids in obese patients and therefore reduce postoperative complications. If patient-controlled opioid analgesia is used, continuous flow should be avoided or used with extreme caution. The administration of opioids should be all the more cautious that the obese subject may have an undiagnosed OSA. Oxygen administration should be continued in the ward until the patient regains his baseline SpO<sub>2</sub> and no longer requires the use of opioids.

To reduce the use of opioids, non-steroidal anti-inflammatory agents or non-drug analgesia may be considered [108]. Different alternatives could reduce opioids use (Opioids Free Anaesthesia [OFA], ketamine and lidocaine infusion), as defined in the Enhanced Recovery After Bariatric Surgery (ERABS) Protocol [88]. Even if some observational studies showed encouraging results [88,108,109] with less opioid use, results of large randomised controlled trials are waited before concluding that such protocols are safe and efficient. It should be kept in mind that the concomitant administration of sedative agents (e.g. benzodiazepines, barbiturates) increases the risk of respiratory depression and airway obstruction.

## 4. Criteria for outpatient surgery or planned postoperative intensive care unit admissions

The recommendations of the French Health Authority (HAS) about outpatient surgery made in 2014 [110] state:

- in the obese patient: patients with a BMI  $< 35 \text{ kg/m}^2$  are eligible for outpatient surgery, except individual contra-indications; patients with a BMI  $> 40 \text{ kg/m}^2$  and an OSA associated, and all the more if it is severe and associated with other comorbidities (pulmonary hypertension, resistant hypertension, major damage to the coronary arteries, resistant heart failure treatment) do not seem eligible for outpatient surgery;
- in the patient with OSA: patients diagnosed with OSA are eligible for outpatient surgery if they have controlled comorbidities, if they are able to use nasal ventilation with CPAP or NIV and if surgery is not painful and does not require the use of opioids postoperatively. In the case of a choice of outpatient care, the intervention could be scheduled in the morning to allow monitoring the rest of the day.



After bariatric surgery, due to the high risk of postoperative bleeding the day following the surgery, benefit/risk of outpatient management should be carefully assessed [7]. Highly trained team have performed laparoscopic sleeve gastrectomy in a daily case manner without increasing the rate of complications [111,112]. It is worth noting that the rate of haemorrhage is greater in the gastric bypass group than in the laparoscopic sleeve gastrectomy group [113].

In case of moderate to severe OSA without preoperative CPAP, or in case of other premorbid comorbidities (mainly respiratory or cardiovascular, confer the chapter “the prevention of perioperative complications”) [114], or in case of major surgery at high risk of postoperative complications [7], the patient will be postoperatively admitted to the intensive care unit (ICU).

## 5. Conclusion

Postoperative complications of the obese patient can be reduced by screening for OSA, involving continuation or initiation of preoperative CPAP or NIV, use of loco-regional anaesthesia rather than general anaesthesia when possible, anticipation of difficult mask ventilation and difficult intubation, reduction of hypnotics and morphine doses and perioperative protective ventilation. This is based on NIV preoxygenation in a semi-sitting position, small TV, moderate PEEP and careful intraoperative recruitment manoeuvres. The optimisation of pre- and perioperative management will be continued postoperatively, with extubation in a semi-seated position, prevention of thromboembolic complications and continuation or early onset of CPAP or NIV, prophylactically or in case of the occurrence of acute respiratory insufficiency.

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Pr. Jaber reports receiving consulting fees from Drager, Hamilton, Maquet, Medtronic, and Fisher & Paykel.

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## Author contributions

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