Curr Atheroscler Rep (2016) 18: 55
DOI 10.1007/s11883-016-0606-1

The Bariatric Patient in the Intensive Care Unit: Pitfalls and Management

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Published online: 27 July 2016

Abstract The increasing number of bariatric/metabolic operations as important alternatives for the treatment of obesity and type 2 diabetes brought several concerns about the intensive care of patients undergoing those procedures. Intensive Care Unit admission criteria are needed in order to better allocate resources and avoid unnecessary interventions. Furthermore, well-established protocols, helpful in many clinical situations, are not directly applicable to obese patients. Indeed, difficult airway management, mechanical ventilation, fluid therapy protocols, prophylaxis, and treatment of venous thromboembolic events have unique aspects that should be taken into consideration. Finally, new data related to planning nutrition therapy of the critically obese have been highlighted and deserve consideration. In this review, we provide an outline of recent studies related to those important aspects of the care of the bariatric/metabolic patients in critical conditions.

Keywords Bariatric · Metabolic surgery · Critical obese · ICU · Monitoring · Mechanical ventilation · Difficult airway · Nutrition · VTE

This article is part of the Topical Collection on *Lipid and Metabolic Effects of Gastrointestinal Surgery*

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Introduction

In the context of an escalating worldwide overweight and obesity pandemic [1], bariatric, and most recently, metabolic surgery have emerged as interesting alternatives [2–4]. Several studies have shown that not only the majority of deaths attributable to overweight and obesity were primarily cardiovascular and cerebrovascular in origin [5, 6, 7••] but also that the morbidity and healthcare expenditures have enormously increased within this particular population segment. According to estimates [8], the US costs of overweight and obesity range from UDS$147 billion to nearly USD$210 billion (in 2005) per year, not to mention the indirect costs linked to absenteeism and low productivity issues. The bariatric/metabolic procedures have the advantages of being associated (although in non-randomized studies and in one small, randomized trial [3]) with improvements in cardiovascular risk factors, decreasing the long-term incidence of cardiovascular events, and improving survival of obese patients [9, 10]. Furthermore, many studies have addressed the morbi-mortality attributable to bariatric/metabolic surgeries [11–15, 16•] and suggest that it depends on three factors: type of operation (endoscopic procedures—i.e., gastric band—are safer than the sleeve gastrectomy which, in turn, is safer than gastric bypass); number of operations executed by the centers; and whether they were done laparoscopically or open surgery. In a recent meta-analysis, Chang et al. [16•] reported an overall perioperative mortality rate (≤30 days after operation) of 0.08 % and a post-operative mortality rate (>30 days after operation) of 0.31 % in the randomized controlled trials evaluated. For observational studies, the same authors found higher both perioperative and post-operative mortality rates 0.22 and 0.35 %, respectively, which could be explained by longer follow-up time or other causes of mortality recorded in that type of study. In any case, these figures are still low and comparable to laparoscopic cholecystectomy [17] and even emergency procedures like appendectomy [18]. But, considering the sustained rise in bariatric/metabolic operations, which reached 468,609 reported procedures worldwide in 2013 [19] (roughly 105,000 in 2015 in Brazil alone—unpublished data), and admitting an average overall mortality rate of 0.30 %, we might conclude that at least 1500 patients die annually worldwide (more than 300 just in Brazil) only by undergoing those procedures. If reoperations and surgical-related complications are included, a more dramatic picture rises. Accordingly, the rate of reoperation can be as high as 7 % and the technical complications can reach 17 % of all procedures [16•]. Therefore, the burden to assist these high-risk surgical patients must involve others beyond surgical and anesthesiology teams, such as cardiologists, respiratory physicians, internists, and infectious disease specialists, since often such assistance will take place in intermediate or intensive care unit (ICU) environment. The role of ICU in that context is both monitoring and giving critical support to patients and preparing them for potential reoperations. In this review, we will summarize some of the major aspects involved in that long journey of looking after critical bariatric patients.

ICU Admission Criteria

In general, obese patients without major medical comorbidities are managed on the standard post-anesthesia care unit (PACU). However, some patients may require at least an intermediate care unit or ICU overnight stay prior to be transferred to regular wards. The current prevalence of obesity in medical-surgical ICU is 5 % [20] with 30.9 % of all referrals being unplanned [21]. ICU admission after bariatric surgery is thus uncommon, but it is often associated with a significantly increased mortality. Anastomotic leaks, conversions, time from operation to ICU admission, and reoperation have the greatest impact in determining the length of hospital stay in the ICU [22]. For obese post-operative patients, BMI represents a risk factor for complications, but the effects on mortality are debatable. In fact, some papers reported higher mortality [23] while others, no effect [24], increases only in complications rate [25] or even lower mortality in obese patients admitted to ICU [26]. Obese patients admitted to ICU, independently of surgical procedures, were more likely to have significant complications but there were no associations with increased mortality [27]. Further, in a large cohort of critically ill patients, underweight was independently associated with a higher hazard of 60-day in-hospital death and overweight with a lower hazard. None of the body mass index (BMI) categories from 30 to higher than 40 kg/m^2 were independently associated with an increased hazard of infection during the ICU stay [26]. The independent risk factors for mortality in obese patients undergoing bariatric surgery are the following: (1) age higher than 45 years, (2) male gender, (3) BMI higher than or equal to 50 kg/m^2, (4) laparotomy, (5) loss of autonomy before surgery, (6) coronary angioplasty, (7) dyspnea, (8) pre-operative intentional weight loss higher than 10 %, and (9) bleeding disorders [28]. However, anastomotic leaks have been consistently reported as one of the strongest independent risk factors of death, and leak-associated mortality has been estimated to be greater than 16 % [25]. We suggest the ICU admission criteria (Table 1).

The presence of severe obstructive apnea (OSA) in that list is also debatable since a recent study showed that intensive monitoring could be superfluous even for these patients [29]. In the presence of at least one of the above criteria, it is recommended to transfer the patient to the intermediate care unit or ICU.

Attempts to stratify patients' risks are important since it can optimize resource allocation and identify the critical ones [30]. Scores might be helpful to prevent delay in intervention or even refer risky patients from operating theater to ICU. The Modified Early Warning Score (MEWS) is a simple, physiological score that may allow improvement in the quality and safety of management provided to surgical ward patients. The purpose of the MEWS is to facilitate prompt communication between nursing and medical staff when deterioration in a ward patient's condition first becomes apparent on the observations chart. MEWS includes monitoring of respiratory rate, heart rate, systolic blood pressure, urine output, temperature, and neurological assessment. The MEWS in association with a call-out algorithm is a useful and appropriate risk-management tool that should be implemented for all surgical in-patients [31]. Following these recommendations, it is possible to further reduce ICU admissions in the post-operative period without loss in patient care.

Airway Management

In obese patients, awareness of a difficult airway and implementation of methods to minimize possible risks are essential [32]. Several studies have shown that airway problems may occur more frequently in obese and morbidly obese patients as compared to normal subjects [33]. Many factors must be taken

Table 1 Intermediate or intensive care unit admission criteria for bariatric patients

Body mass index (BMI) ≥50 kg/m^2
Severe obstructive sleep apnea (OSA) or obesity hypoventilation syndrome (OHA) and/or non-invasive mechanical ventilation requirements
Need for respiratory and cardiac monitoring
Difficult glycemic control
Intra-operative surgical or anesthetic complications*

*Bleeding, cardiovascular or respiratory event, accidental lesions into consideration as possible predictors for difficult mask ventilation in obese patients such as the following: (1) BMI higher than 30 kg/m^2 as well as presence of a metabolic syndrome [34], (2) short neck, (3) higher neck circumference (e.g., >41 cm in women and >43 cm in men), (4) Mallampati score III/IV, and (5) mandibular protrusion [35, 36]. Concurrently, the presence of high Mallampati score at III or IV, OSA with a STOP BANG score higher than 5 [37, 38], and reduced cervical mobility have been proposed as possible risk factors for difficult intubation. An interesting score that can be easily adopted to predict difficult intubation in obese patients and manage the airways accordingly is the so-called El Ganzouri risk index (EGRI) [39•]. It includes the following: (1) mouth opening, (2) thyromental distance, (3) Mallampati class, (4) neck movement, (5) ability to prognath, and (6) body weight and history of difficult intubation, each of them scored from 0 = low, 1 = medium, to 2 = high risk. We recommend the following procedure: If EGRI is between 0 and 3, no difficulties for intubation are expected. If EGRI is between 4 and 7, a video laryngoscope is suggested to improve visibility of the larynx during intubation. If EGRI is higher or equal to 8, an awake intubation with fiberscope is recommended. Another important parameter to be considered before intubation is the non-invasive measurement of oxygen saturation (SpO_2) in ambient air which has been found associated with possible further desaturation at intubation and in the post-operative period. If SpO_2 is lower than 95 %, a pre-operative arterial blood gas analysis should be performed to assess pCO2, standard bicarbonate for diagnosis assessment of OSA and OHA.

Mechanical Ventilation

The optimization of intra-operative mechanical ventilation is essential to minimize complications during surgery and in the post-operative period. Further, similar considerations apply for ventilatory management of obese patients admitted to ICU in the post-operative period. Major alterations in respiratory mechanics occur in obese patients undergoing anesthesia or deep sedation [40]. There is no evidence of superiority of volume- vs. pressure-controlled ventilation [41]. Theoretically, pressure-controlled ventilation could lead to a more homogeneous air distribution within different lung compartments. On the other side, volume-controlled ventilation may allow for better control of tidal volumes during surgical procedures where chest wall elastance is affected (e.g., abdominal surgery). Further, the most important aspect during mechanical ventilation for optimizing gas exchange and minimize possible ventilator-induced lung injury is the level of pressure reached at end inspiration and end expiration, which are effectively the same in both pressure- or volume-controlled ventilation. Obese patients are currently ventilated with higher tidal volumes standardized for predicted or ideal body weight as compared to normal subjects [42, 43]. Higher tidal volumes have been reported to be associated with increased risk of ventilator-induced lung injury (VILI) and post-operative pulmonary and extrapulmonary complications, as well as prolonged hospital stay [44, 45]. Recently, attention has been given to the role of driving pressure to minimize the risk of post-operative pulmonary complications. Driving pressure is the difference between inspiratory plateau pressure and end expiratory pressure. The driving pressure might induce VILI, increasing the stress and strain of the airways as well as the different pulmonary structures including the extracellular matrix and the alveolar capillary membrane. Lower levels of driving pressure have been found associated with reduced post-operative pulmonary complications, with a reduction of 6 % per cm H_2O of driving pressure [46]. Interestingly, in this study when PEEP application was associated with an increase in driving pressure, this was paralleled by an increase in the risk of post-operative pulmonary complications and worse outcome. We hypothesize that driving pressure is associated with an increase in the amount of energy delivered to the lung parenchyma ($\text{Energy} = \text{Driving pressure}^2 \times \text{Compliance of the respiratory system}/2$). The energy is paralleled by the power that results from the energy per breath, times the respiratory frequency. Thus, the ventilatory setting during anesthesia and in the immediate post-operative period, especially in obese patients, should include low tidal volume to minimize driving pressure as well as energy per breath, and the minimal respiratory rate to achieve adequate gas exchange to minimize power. The role of PEEP during surgery has been recently debated [47–49]. In obese patients, it has been shown that application of PEEP and recruitment maneuvers improved oxygenation and respiratory system complication [50•, 51] which were also confirmed in two meta-analyses [41, 52•]. It has also been reported that in post-operative mechanically ventilated obese patients in ICU, a recruitment maneuver followed by individual PEEP titration was found to significantly improve lung volume, respiratory system elastance, and oxygenation [53]. However, small randomized controlled trials did not show any benefit after extubation of an intra-operative strategy including higher levels of PEEP and recruitment [54, 55]. Another study [56] showed that the optimal time of application of positive pressure is in the immediate post-operative period immediately after extubation, because it reduces the incidence of atelectasis and the concomitant reduction of loss of expiratory reserve volume. It must also be taken into account that higher PEEP levels may yield the need for increased fluids requirements [57]. In any case, whatever PEEP is selected in morbidly obese patients, it should not be associated with an increase in driving pressure [46]. Finally, inspiratory oxygen fraction must be carefully controlled during surgery. Obesity facilitates wound infection, and a higher concentration of inspired oxygen was sought to protect against this complication [58]. However, in patients with BMI more than 30 kg/m^2, a multicenter large randomized controlled trial showed no difference in surgical site infections based on two different inspired oxygen fractions (30 and 80 %) [59]. We believe that without strong evidence for high inspired oxygen to reduce infections, its adverse effects might become relevant. Additionally, lower oxygen concentrations can reduce the amount of atelectasis, especially in the obese [60]. Thus, at present, we suggest the following intra-operative strategies in obese patients: (1) low tidal volume at 6–8 ml/kg predicted or ideal body weight; (2) low driving pressure below 13 cm H_2O; (3) PEEP between 5 to 10 cm H_2O, but never associated with an increase in driving pressure; and (4) recruitment maneuvers should be performed only before PEEP setting and as a rescue therapy. In case they are used, we propose a simple maneuver which associates the increase in PEEP at 10 cm H_2O, followed by progressive increase in tidal volume or inspiratory pressure to reach the open up pressure required. Bag squeezing or systems which do not permit adequate monitoring of inspiratory pressure achieved during the maneuver are not recommended; (5) minimal respiratory rate and inspiratory oxygen fraction to achieve adequate gas exchange. The ongoing multicenter RCT Protective Ventilation with Higher versus Lower PEEP during General Anesthesia for Surgery in OBESE Patients (PROBESE) will provide more data on this topic.

Post-operative Management

Obese patients are at higher risk to develop post-operative complications, mainly pulmonary ones [40, 61••]. Thus, it is reasonable to consider, at least in patients at higher risk, transferring them to post-operative monitoring areas as we have remarked above. The intensity in assistance level from hospital ward to intensive care should consider the parameters detailed in Table 1. It has been demonstrated that patients with severe OSA treated with adequate non-invasive CPAP are at low risk of cardiopulmonary complications after (laparoscopic) bariatric surgery. Thus, routine admission to an ICU might be superfluous, but continuous digital oximetry remains essential in the post-operative period in obese patients at risk [29]. It is also important to emphasize that the nurse workload for obese patients does not seem to increase regarding non-obese patients admitted to ICU [62]. We believe that the following therapeutic managements should be routinely adopted in the post-operative period on obese subjects: (1) sitting or head-up positioning in the bed, avoiding the patient lying in supine position on the bed, if not clinically contraindicated; (2) early mobilization, cough incentive, and deep breathing; and (3) pain management—but caution is required with the use of long-acting opioids and sedatives. A small randomized controlled trial showed that the application of these three easy maneuvers, performed bedside by nurses and physiotherapists in the ward or ICU, reduced dramatically the incidence of post-operative pulmonary complications, particularly in obese subjects after abdominal surgery [63]. In the ward, oxygen therapy (consider post-operative nCPAP in OSA or OHS patients previously treated with positive-pressure devices) should be continued until baseline arterial oxygen saturations are achieved. Thus, simple therapies including monitoring clinical conditions of the patients in the first 24 h post-operatively should be guided by severity of the underlying comorbidities, requirement for post-operative parenteral opioids, and the surgical procedure itself. We also recommend the monitoring of initial signs of sepsis in two or more of the following: (1) mental status alteration, (2) systolic blood pressure less than 100 mmHg, and (3) respiratory rate higher than 22 per minute [64]. Additionally, since post-operative oxygen desaturation is common in obese patients [65] and may be associated with increased risk of prolonged hospital length of stay and death, we suggest adding careful monitoring of oxygen saturation in the post-operative period to early detect pulmonary complications and start appropriate treatment. The use of non-invasive respiratory treatment has been found effective to reduce pulmonary complications and ICU admission after surgery [66]. Particularly in the pre-operative hypoxemic obese, treatment with supplemental oxygen alone may even worsen respiratory dysfunction by aggravation of carbon dioxide retention [67]. Thus, early and preventive application of positive airway pressure (non-invasive CPAP or PPV) represents an effective treatment option [68]. The use of non-invasive CPAP device as early as possible after extubation should be always considered for patients with a history of OSA or OHA and for those with unknown high risk of OSA or OHA. In patients with OHA, non-invasive positive ventilation should be also considered. However, it is not yet clear if this should be a preventive treatment, or if it should be initiated only in the presence of initial signs of respiratory failure.

An additional and important aspect related to post-operative clinical management, independently from the ward or ICU, is appropriate fluid balance and hemodynamic monitoring from the intra-operative to the post-operative phases. Implementation of goal-directed fluid therapy protocols can prevent intra-operative fluid overload in patients undergoing bariatric surgery, with consequent improvement in outcomes, e.g., decreasing post-operative nausea and vomiting (PONV) or even hospital length of stay [69].

Venous Thromboembolism: Prophylaxis and Treatment

The risk of venous thromboembolism (VTE) is increased in obese patients, and the role of deep vein thromboprophylaxis after surgery has been well demonstrated [70–74]. Some indexes have been proposed to predict the risk of VTE in obesity after surgery, like the Caprini score—when higher than or equal to 4, representing a threshold for high to moderate risk [75]. However, there is no consensus on how prophylaxis and even treatment of VTE in obese patients, whether undergoing bariatric surgery or hospitalized in ICU for other reasons, should be undertaken. There is also no manufacturer guidance on if the dose of anti-thrombotic drugs needs to be increased in that particular population or by how much [76••]. Many studies recommend capping doses based on weight but few services seem to adopt it [77]. If on the one hand, it seems reasonable that anti-coagulation, use of sequential compression devices (SCDs) on the lower extremities perioperatively, and early ambulation reduce the incidence of venous thromboembolism (VTE) post-operatively; on the other hand, the evidence on which this recommendation has been based is not particularly strong [78]. The benefit of routine anti-coagulation prophylaxis has been described in other surgical populations at increased risk but without high-level evidence or trials. Both unfractionated heparin (UFH) and low molecular weight heparin (LMWH) have been used extensively in bariatric surgery. A systematic review that included 30 publications of open and laparoscopic bariatric procedures concluded that it is reasonable to use UFH 5000 IU subcutaneously every 8 h or LMWH 30–40 mg every 12 h starting before surgery and in combination with sequential compression devices, while acknowledged that there are no strong evidence supporting such recommendations [79]. Another large study concluded that LMWH is more effective than UFH for prevention of VTE among patients undergoing bariatric surgery and does not increase the risk of bleeding [80]. However, it should be noted that 98 % of the patients included in this study also received mechanical prophylaxis with sequential compression devices, and 3.2 % of the patients had prophylactic inferior vena cava (IVC) filters placed [80]. Bleeding complications associated with chemoprophylaxis has been reported reaching 2 % of incidence when a standardized definition of hemorrhage was used [81]. From a health care payer perspective, the use of the LMWH dalteparin for VTE prophylaxis among critically ill medical-surgical patients was more effective and had similar or lower costs than the use of UFH [82]. Some studies have examined the use of mechanical methods as single means to prophylaxis in bariatric patients [83, 84]. But the ability to generalize these results is limited since they are retrospective single-practice experiences with fewer complications over time. Thus, mechanical methods alone, such as intermittent pneumatic compression or graduated compression stockings, have not been recommended as the isolated prophylactic means in bariatric patients since their risk is at least moderate (Caprini score, 3–4) [71, 85].

Since the vast majority of thrombotic events in bariatric patients occur after hospital discharge [14, 85], there is a relevant clinical question about what patients should receive extended prophylaxis, and some studies have been addressing this issue recently [86, 87••]. Indeed, Aminian et al. [87••] accessing a large US database identified 91,963 patients who underwent bariatric operations between 2007 and 2012. They found that the prevalence of post-discharge VTE (including DVT and PE) was 0.29 %, which increased the mortality rate to 2.6 %. More than 80 % of post-bariatric surgery thromboembolic events occurred after hospital discharge [87••]. Taking into account these figures, the authors identify the patients potentially at risk who should receive an extended prophylaxis. The ten most important medical conditions were the following (with their respective odds ratio in brackets): previous cardiac heart disease (OR = 6.58), paraplegia (OR = 5.71), reoperations (OR = 5.11), dyspnea at rest (OR = 3.95), non-gastric band surgery (OR = 2.44), age > 60 years (OR = 1.96), male sex (OR = 1.92), BMI > 50 kg/m^2 (OR = 1.67), length of stay > 3 days (OR = 1.58; 95 %), and operative time > 3 h (OR = 1.57). On the basis of the regression equation and the above parameters, a very useful risk calculator was developed (that can be accessed at https://apervita.com/community/clevelandclinic (free registration required) under the “obesity” formula tab) providing the percentage estimates of post-discharge VTE after bariatric surgery. The post-bariatric patients could then be stratified into moderate risk (<0.4 %), high risk (between >0.4 and <1 % or one of the following: past history of DVT or PE, congenital or acquired hypercoagulable conditions [e.g., positive factor V Leiden, prothrombin 20210A], and relevant chronic venous insufficiency), and very high risk (>1 %). Based on these findings, it was recommended that patients with high or very high attributed risk are suitable to extended prophylaxis (two additional weeks under anti-thrombotic agents. See Table 2 for drugs and dosages).

The development of the new oral direct thrombin and factor Xa inhibitors anti-coagulant drugs has been considered a revolution in the prophylaxis and treatment of acute VTE [76••, 88]. Currently available information does not suggest a need for dose adjustment for any of the most used drugs (i.e., dabigatran, rivaroxaban, apixaban, and edoxaban) for overweight/obese patients but there are very few data directly addressing that issue. We recommend monitoring anti-Xa activity in order to ascertain the anti-coagulant effect [89]. Most clinicians would rather prefer UFH, LMWH, or vitamin K inhibitors as necessary since much more information is available about these drugs.

Another important clinical issue about VTE prophylaxis in bariatric patients is the use of inferior vena cava (IVC) filters. IVC filters may be considered in high-risk patients, including those with previous VTE, venous stasis disease, truncal obesity, a BMI of 60 kg/m^2, hypercoagulable disorders, and obesity hypoventilation syndrome, but the long-term complications and the lack of strong evidence supporting its use make that devices not recommended in VTE prevention of bariatric patients [24, 90, 91••].

Nutrition

Methodologies used to assess bedside nutritional status, such as anthropometry and bioimpedance, come up against many

Table 2 Recommendations for anti-coagulant therapy commonly used in post-bariatric surgery

	VTE prophylaxis	VTE treatment
Heparin	- Preferred in renal failure - 5000 U 2/3 times a day - Adjusted doses up to 15,000 U two times a day used without increase bleeding	- Data available support use of TBW based dosing (104). - Monitoring using the aPTT required
Enoxaparin	BMI 30 to 49 kg/m^2: 0.5 mg/kg or 40 mg every 12 h BMI >50 kg/m^2: 0.5 mg/kg or 60 mg every 12 h	BMI 30 to 49 kg/m^2: 1 mg/kg every 12 h based on ABW. Once daily dosing regimens of enoxaparin are not recommended.
Dalteparin	• 2500 IU SC 1–2 h pre-op, thereafter 2500 units SC qDay • High risk of thromboembolic complications (eg, malignancy): 5000 units SC evening before surgery, then 5000 units qDay (first dose may be evenly split in a pre-op and post-op dose)	200 units IU/kilogram SC qDay for 30 days, then Months 2–6: 150 units/kilogram SC qDay Not to exceed 18,000 units daily Treatment Duration: 5–10 days usual Severe Mobility Restriction: 5000 units SC qDay Thrombocytopenia: Dose Reduction • Plts 50,000–100,000/mm^3: Reduce daily dose by 2500 units until 100,000/mm^3 • Plts <50,000/mm^3, discontinue until >50,000/mm^3 Renal impairment, severe: dose reduction • CrCl < 30 ml/min: monitor anti-Xa level to determine appropriate dose

TBW total body weight, *BMI* body mass index, *SC* subcutaneous, *Plts* platelets

limitations in obese patients, and the higher the BMI, the harder it is to interpret the findings. In these cases, it is more effective to apply nutritional risk screening methods [92, 93], for they take into account the inflammatory state and protein catabolism of acute conditions and pre-existing illnesses. Indirect calorimetry, despite its drawbacks, is considered the gold standard for measuring actual energy consumption [94].

The estimate of energy expenditure in the absence of indirect calorimetry can be performed using predictive formulas such as Penn State, Ireton-Jones, and Mifflin; however, there is a risk of overestimating caloric needs and it is recommended to offer between 60 and 70 % of the calculated value. Another way of estimating the energy goal is through a rule of thumb: 11–14 kcal/kg actual weight for patients with BMI between 30 and 50 kg/m^2 and 22–25 kcal/kg ideal weight for patients with BMI above 50 kg/m^2 [95, 96]. The protein targets are based on ideal weight according to the degree of obesity, with 2.0 g/kg of ideal body weight for BMI obesity I and II (30 to 39.9 kg/m^2) and 2.5 g/kg ideal weight for BMI obesity III (>40 kg/m^2). Therefore, a hypocaloric, hyperproteic offer is recommended for patients with BMI greater than 30 kg/m^2, considering the potential benefits of calorie restriction to obese patients [96, 97]. Being that serious diseases and obesity have synergistic pro-inflammatory effects, the critically obese patient presents a high rate of catabolism and muscle consumption inducing a state of sarcopenic obesity [95, 96] that will result in a severe functional sequelae for these patients post-ICU.

It is important to note that during the implementation of enteral nutrition therapy to critically ill patients prematurely, there are difficulties in the progression of calorie-protein offer which can delay the achievement of the goals established in the first 4 weeks of treatment, creating a difference between energy supply and demand [98]. The accumulated difference between actual offer and desired caloric needs is called energy deficit and is associated with longer periods of mechanical ventilation, ICU stay, antibiotic intake, and infectious complications [98].

Early enteral nutrition in severely obese patients must be implemented—not unlike with other critical patients in intensive care—being the preferred route of calorie-protein offer because it helps alleviating the pre-existing oxidative stress state. There is no justification to make obese patients fast admitting the existence of body reserves. Such practice exacerbates the loss of lean body mass and induces the development of sarcopenia. The benefits observed with the establishment of the early enteral nutrition will only be achieved with the minimum offer of 50–65 % of the pre-defined goals. Some features of the obese patient interfere with gastric motility, hindering gastric voiding and increasing the enteral offer intolerance risk at this point of the digestive tract. Among them feature increased abdominal pressure and neuropathy secondary to hyperglycemia. In this condition, the preferential use of the post-pyloric position of the enteral probe may minimize the risk of gastroesophageal reflux and aspiration in these patients [96].

The protein offer in severely obese patients should reach 40 to 50 % of the resting energy expenditure (REE). This strategy allows the reduction of carbohydrate offer without increasing protein catabolism (118). The amount of protein per kilogram of body weight should be higher and proportional to BMI [99–101]. The permissive hypocaloric offer derives from the "protein-sparing modified fast" method [100], where the reduction of caloric offer to 30–70 % of the estimative is accompanied by the increase of protein offer by 50–60 % of the calories offered. The benefits of caloric restriction include improvements in glycemic control and peripheral insulin resistance, as well as prevention of the metabolic consequences of hyperalimentation, such as hypercapnia, water retention, and hypertriglyceridemia. Although loss of weight and body fat are observed, they should not be the primary objective of nutritional support during ICU stay.

L-Leucine—present in whey—activate the muscle protein synthesis via the mammalian target rapamycin (mTOR) way when in proportions greater than 10 % of the offered protein content [102, 103]. L-Arginine also seems promising in improving tissue perfusion by modulating vascular tonus through nitric oxide synthase (NOS), and may reduce pulmonary artery pressure, maximum and minimum blood pressures, while increasing the use of branched-chain amino acid (BCAA) by the muscles [101]. Therefore, not only the quantity but also the quality of the offered proteins should be taken into consideration when planning nutrition therapy of the critically obese.

Conclusions

The perioperative management of obese patients during bariatric/metabolic surgery is complex and requires careful consideration. A clear diagnostic, clinical, and treatment pathway must be implemented and followed by a multidisciplinary team taking into consideration pre-, intra-, and post-operative phases. Adequate selection of patients at risk, appropriate respiratory and fluid management, as well as implementation of vital functions monitoring in the ward or intermediate care or intensive care unit according to the individual clinical situation, may improve outcome of obese patients undergoing general anesthesia and surgery.

Compliance with Ethical Standards

Conflict of Interest Carlos E. Pompilio, Paolo Pelosi, and Melina G. Castro declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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•• Of major importance

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