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PROBLEMS DURING HOSPITALIZATION OF MORBIDLY OBESE PATIENTS IN INTENSIVE CARE UNITS: A NARRATIVE REVIEW

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A – study design, **B** – data collection, **C** – statistical analysis, **D** – interpretation of data, **E** – manuscript preparation, **F** – literature review, **G** – sourcing of funding

ABSTRACT

Background: The frequency of hospitalization of patients with morbid obesity (Body Mass Index – BMI≥40 kg/m^2) is constantly increasing. When these patients are hospitalized in the Intensive Care Units (ICUs), in addition to the common problems in care and treatment encountered in the rest of the hospital wards, it brings distinct challenges to be faced by the staff.

Aim of the study: This review aims to clarify the distinctive physiological characteristics of morbidly obese patients and the resulting challenges during ICU hospitalization while presenting appropriate therapeutic approaches and interventions.

Material and methods: Based on the available medical literature and the authors' clinical experience, we have selected articles and guidelines using PubMed, National Institutes of Health (NIH), SpringerMedizin, Semantic Scholar, the Medycyna Praktyczna website, WHO data, and book sources. We reviewed 693 articles, 3 books, and the websites of WHO and Medycyna Praktyczna. The final selection comprised 34 articles (32 in English, 1 in German, 1 in Polish), published between 2004 and 2023, with 12 published after 2020.

Results: Morbid obesity disrupts the physiological homeostasis of the body. It most noticeably affecting the respiratory, cardiovascular, or gastrointestinal systems while being associated with multiple diseases. This necessitates specific distinctions in the intubation procedure, mechanical ventilation strategy, and drug dosing. In addition, life-threatening conditions such as acute respiratory distress syndrome (ARDS) or sepsis occur among patients hospitalized in the ICU, requiring additional modifications to therapy.

Conclusions: Morbidly obese ICU patients, due to their anatomical and physiological characteristics, belong to individuals at risk of difficult intubation requiring specific positioning, preoxygenation, the use of video laryngoscopes, and implementation of an appropriate mechanical ventilation strategy. Additionally, altered drug metabolism and distribution in these patients necessitate distinct dosing protocols for effective treatment.

KEYWORDS: obesity, morbidity, critical care, intubation, ventilation, sepsis

Background

For clinical reasons, obesity is assessed according to the Body Mass Index scale (BMI) (kg/m^2). According to the World Health Organization (WHO), the classification of being overweight and obese can be divided by BMI: overweight BMI 25-29.9 kg/m^2, I° obesity 30-34.9 kg/m^2, II° obesity 35-39.9 kg/m^2 and III° - morbid obesity with a BMI 40 kg/m^2 or over. According to WHO, in 2016, 13% of adults aged 18 and older were obese worldwide [1]. On a global scale, compared to 1975, the number of people affected by obesity has almost tripled. In addition, prognoses suggest that by 2030, 1 in 2 United States residents will be obese, and as many as 1 in 4 will be severely obese (≥35) [2]. Multimorbidity is a common problem in this group of patients. Diabetes, hypertension, dyslipidemia, ischemic heart disease, hyperuricemia, gout, diseases of the genitourinary system, hormonal disorders, sleep apnea and degenerative diseases of the musculoskeletal system and spine are the most common comorbidities. In obesity, drug biotransformation and pharmacokinetics are correlated with an abnormal elevation of fat tissue. Total body water in patients with normal weight is about 65%. Conversely, in obese patients, this amount is decreased to 40%. Therefore, drug distribution volumes are changed. It is critical to remember that lipid solubility becomes of importance in the case of drugs with high fat solubility (i.e.: fentanyl) [3].

Aim of the study

The aim of this study is to outline the distinctiveness and challenges that arise from the care and treatment within intensive care units of morbidly obese patients. We focused on presenting the physiological distinctiveness and outlining the most appropriate management strategy for typical intensive care procedures such as tracheal intubation, mechanical ventilation, and drug dosing while focusing on groups complicated by ARDS and sepsis.

Material and methods

We searched the available medical literature on PubMed, National Institutes of Health (NIH), SpringerMedizin, Semantic Scholar databases, guidelines on the Medycyna Praktyczna website, data on the WHO website and book items. The searched articles between 2000 and 2024 in English, Polish, and German in the online databases contained keywords overlapping with the main section headings preceded by the phrase 'morbid obesity' and ending with 'ICU'. In total, we searched 693 articles, 3 books, and the websites WHO and Medycyna Praktyczna. The inclusion criterion for abstracts were those that addressed: (1) obese adult population; (2) intubation; (3) mechanical ventilation; and (4) drug dosing in patients undergoing anesthetic care in the ICU setting and/or the operating room. Studies that considered only overweight and pediatric patients were excluded. Finally, we selected 34 articles (32 in English, 1 in German and 1 in Polish) published between 2004 and 2023, including 12 published in 2020 and later, 1 WHO report, and 1 book in Polish.

Results

1. Physiological distinctions in morbidly obese patients

1.1 *Respiratory system*

In obese individuals, anatomical changes and increased intra-abdominal pressure due to heightened pressure on the diaphragm lead to numerous alterations in the respiratory system. This results in reduced functional residual capacity (FRC), expiratory reserve volume (ERV), vital capacity (VC), total lung capacity (TLC), lung tissue compliance, and forced expiratory volume in one second (FEV1). Additionally, the restrictive action of adipose tissue on the chest wall markedly decreases its compliance.

Airway resistance and oxygen consumption by tissues is increased due to the presence of a large amount of adipose tissue. Consequently, the diffusing capacity of carbon dioxide (CO_2) and the alveolar-arterial oxygen gradient are reduced, secondary to the increased oxygen (O_2) consumption by tissues. In addition, respiratory effort intensifies due to increased airway resistance and decreased chest wall compliance.

The mechanical properties of the lungs and chest wall undergo substantial changes in obesity, mainly due to fat deposition in the mediastinum and abdominal cavities. These changes lead to reduced compliance of the lungs, chest wall, and the entire respiratory system. This contributes to respiratory symptoms characteristic of obesity, such as wheezing, dyspnea, and orthopnea. Furthermore, the decreased compliance of the respiratory system (increased stiffness) alters the breathing pattern. Normally, air moves into the lungs following the negative pressure gradient in the pleural cavity. However, in obesity, intra-abdominal and pleural pressures slightly increase because the downward movement of the diaphragm and the outward movement of the chest wall are restricted by fat accumulation in the chest and abdominal cavities. This leads to reductions in both ERV (Expiratory Reserve Volume) and FRC (Functional Residual Capacity). The reduction in FRC is proportional to the degree of obesity - overweight, moderately obese, and severely obese individuals, not suffering from asthma, exhibit FRC reductions of approximately 10%, 22%, and 33%, respectively. Additionally, Tidal volume (TV) is somewhat lower in obese individuals. However, a slight increase in the mean respiratory rate compensates for the shallow breathing pattern, resulting in a substantial increase in overall minute ventilation [4, 5]. Moreover, approximately 67% of all morbidly obese patients suffer from obstructive sleep apnea (OSA) [6]. Furthermore, it should be remembered that the specific anatomical features expose these patients to difficult intubation and rapid desaturation, which requires appropriate methods in the intubation and preoxygenation technique, as described in paragraph 2.1 [5, 7, 8].

Table 1. Changes in physiological parameters of the respiratory system in obese patients [4, 5, 6]

The following parameters are reduced	The following parameters are increased
VC – vital capacity	Airway resistance
TLC – Total Lung Capacity	Breathing effort
FRC – Functional residual capacity	DLCO – Diffusion capacity of carbon dioxide
ERC – Exhalation Reserve Capacity	AdDO2 - Alveolar-arterial oxygen gradient
FEV1 – Forced expiratory volume in one second	Oxygen consumption in tissues
Lung and thoracic tissue compliance	

1.2 *Cardiovascular system*

Obesity and hypertension are associated with structural and functional alterations in large arteries, manifesting as increased arterial stiffness and subsequent reduced compliance and elasticity. However, the changes in small resistance arteries are particularly critical, playing a significant role in the pathogenesis of ischemic cerebrovascular events, coronary artery disease, and renal failure. These microvascular alterations have a marked prognostic impact in obesity-related conditions, such as hypertension. Additionally, obese patients exhibit a higher prevalence of essential hypertension, hypercholesterolemia, secondary ischemic heart disease and atrial fibrillation [9].

Hypercholesterolemia affects the coronary arteries while posing an increased risk to other vascular regions, including the central nervous system and peripheral circulation. This condition is associated with systemic vascular changes that can lead to various complications. High cholesterol levels can lead to microvascular dysfunction and impaired tissue perfusion, resulting in organ dysfunction and systemic issues such as skin changes, kidney dysfunction, and hypertension. Additionally, this impairment contributes to atherosclerosis, which can affect the central nervous system and cause conditions such as cerebrovascular accident (CVA) and cognitive decline due to reduced blood flow to the brain. In peripheral circulation, hypercholesterolemia can lead to peripheral arterial disease (PAD), which manifests as intermittent claudication - a condition characterized by muscle pain during exercise due to inadequate blood flow [10].

Furthermore, obesity is independently associated with left ventricular hypertrophy (LVH). While the left ventricular mass may be increased in obesity, it is typically proportional to body size if no other comorbid conditions are present. Most studies indicate that individuals with obesity exhibit an increased left ventricular cavity size and wall thickness, with eccentric hypertrophy being predominant.

The mechanisms influencing left ventricular geometry and function in the context of obesity include visceral fat distribution and its secreted products (adipokines, angiotensin II, inflammatory cytokines). Additionally, obesity leads to hyperinsulinemia and insulin resistance with growth-stimulating effects. Subsequent elevated blood pressure has an additive effect on myocardial remodeling. OSA affects nocturnal blood pressure, adrenergic stimulation, and chronic hypoxemia [11].

1.3 *Digestive system*

Being overweight or obese are major independent risk factors for the development of gastroesophageal reflux disease (GERD). They increase intra-abdominal pressure and promote the formation of hiatal hernias. Studies using pH impedance measurements have shown that the prevalence of both acid and non-acid reflux directly correlates with BMI. A broad range of pathophysiological changes is associated with the heightened risk of GERD in obese individuals, including excessive salivation, esophageal motility disorders, increased transdiaphragmatic pressure gradient, and more frequent spontaneous relaxation of the lower esophageal sphincter.

Obesity alters neurohumoral regulation and gastric motility, with overweight and obese patients showing marked increases in fasting gastric volumes. Elevated gastric pH and prolonged food retention are common in these individuals. Additionally, obesity has been linked to erosive and ulcerative changes in the gastric mucosa [12].

2 Distinctions of morbidly obese patients in the intensive care unit

2.1 *Tracheal intubation*

There is no doubt that obese patients are among the group at increased risk of difficult intubation. This is due to anatomical differences such as a disproportionately short and thick neck, excess soft tissues deposited near the larynx and palate, an anteriorly protruding larynx, a relatively large tongue and thick cheeks, and impaired mobility of the cervical spine and a lofty thoracic level, further complicating the insertion of the laryngoscope [8]. However, it appears that elevated BMI itself is not an accurate predictor of difficult intubation [13]. In these patients, an enlarged neck circumference is a markedly better indicator [8, 13]. Obese patients belong to a group of patients who are particularly susceptible to rapid desaturation (mainly due to reduced FRC), and therefore separate preoxygenation modalities are required before intubation, compared to normal-weight patients. The reference method of preoxygenation is non-invasive ventilation (NIV), where continuous positive airway pressure (CPAP) is most commonly used, protecting the airway from collapse, thereby improving blood oxygenation, providing a longer time to intubation. It is particularly recommended for OSA, a characteristic complication of severe obesity. In addition, in certain clinical situations, such as temporary apnea or in a rapid sequence intubation (RSI) procedure, High-Flow nasal cannula (HFNC) can be effective. To ensure proper airway patency and prevent atelectasis, preoxygenated obese patients should be in a sitting or lying ramped position. Traditional mask-and-bag ventilation should be avoided, as this is an additional factor that promotes faster desaturation [5,7].

Due to the need for prolonged ventilation in the ICU and the necessity to use endotracheal tubes (and, in selected cases, tracheostomy tubes) for this purpose, we will not compare them with supraglottic methods in this article.

As far as laryngoscopy itself is concerned, video laryngoscopes are recommended for laryngoscopy of the larynx in obese patients, which gives much better results than direct laryngoscopy with a traditional Macintosh laryngoscope. With the use of video laryngoscopes, indicators such as the number of successful intubations and procedure times, or better visualization of the larynx, have improved [14]. Furthermore, Seongheon Lee et al. demonstrated that in patients with morbid obesity (BMI ≥ 35 kg/m2), the ramped position (with head and upper body elevated) made also intubation and its timing with a video laryngoscope easier, moreover, it facilitated mask ventilation, which was ineffective and contraindicated in this group of patients. With this positioning, the oral, pharyngeal and laryngeal axes are properly aligned [13]. Moreover, in case of failure of video laryngoscopy, it should be remembered that there is the possibility of intubation by broncho-fiberscope [8].

One of the studies conducted by De Jong et al. provided interesting and noteworthy results [15]. It reports that difficult intubation in obese patients (BMI ≥ 30 kg m2) occurred 2 times more frequently in intensive care units than in the operating room setting (16.3% and 8.2%, respectively, out of 282 and 2103 study groups). Furthermore, severe, life-threatening intubation complications occurred 20 times more frequently in intensive care units.

2.2 *Mechanical ventilation, including patients with ARDS (Acute Respiratory Distress Syndrome)*

The above described changes in the respiratory system of morbidly obese patients necessitate certain changes in mechanical ventilation methods. Particularly influential in disrupting gas exchange and causing rapid desaturation is the susceptibility to forming atelectatic fields in the lungs. It is confirmed that the most effective position for mechanical ventilation of obese patients is prone or seated, allowing the pressure on the diaphragm to be relieved and the previously compressed areas of the lungs to be ventilated [5,7]. In the case of ARDS (Acute Respiratory Distress Syndrome), especially in obese patients (who are more likely to develop ARDS), prone position ventilation is recommended (remembering, however, that this group of patients is at particular risk of hypotension, secondary oliguria, and hepatic hypoxia due to significant pressure on blood vessels in the abdominal cavity) [5,6].

Lower tidal volumes (TV) are recommended in morbidly obese patients, both suffering and not suffering from ARDS. Lower tidal volumes (TV) are recommended in morbidly obese patients with and without ARDS, preventing excessive volume damage to the lungs and the development of inflammation. TV should be selected on the basis of predicted body weight (PBW), which should not be merely estimated, so as not to inflict more than the correct volume [5]. It is recommended to set 6 to 8 ml/kg PBW in combination with moderate to high positive and expiratory pressure – PEEP (7-20 cm H_2O) to prevent the formation of secondary atelectasis. Recruitment maneuvers (RM) are recommended beforehand to aerate the previously formed atelectatic areas. It consists of a brief increase in inspiratory pressure and there are a number of techniques developed to carry it out. However, it should be considered that morbidly obese patients may require higher pressures than non-obese patients, and values in the order of 50 cm H_2O in those without lung injury may not result in complete opening. The use of the previously mentioned PEEP in patients undergoing RM is necessary to maintain ventilated recruited lung areas. However, it is imperative to note that RM should be individually selected and should not be used in hemodynamically inefficient patients, as it causes a decrease in venous return with a subsequent decrease in cardiac output and blood pressure. Furthermore, in patients with structural injury to the lungs such as emphysema, for instance, it may result in pneumothorax or mediastinal emphysema.

The use of tidal volumes in the range of 6 to 8 cm H_2O/kg PBW, moderate to high PEEP and RM is referred to as lung protective ventilation, which has been proven to be effective in ARDS patients [5,7].

It should be noted that morbidly obese patients are characterized by higher CO_2 production. Therefore, the respiratory rate should be higher than in non-obese patients; studies have indicated a rate in the range of 15 to 21/minute [23]. At the same time, hyperventilation should be prevented, as hypocarbia ($PaCO_2$ – partial pressure of carbon dioxide <30 mmHg) may result in increased pulmonary leakage. Thus, end-tidal carbon dioxide ($EtCO_2$) should be maintained at the upper limit of normal [8].

There is no clear consensus on the superiority of a particular ventilation method from pressure-controlled to volume-controlled ventilation. The choice of technique should, therefore, be tailored to the individual patient [8, 16]. Pressure-assisted ventilation (PSV) appears to be highly beneficial in this patient group. However, studies on the use of new promising modes of ventilation, such as neurally adjusted ventilatory assist (NAVA), proportional assisted ventilation (PAV) and adaptive support ventilation (ASV) are required [7].

Before extubating, sedation should be stopped as soon as possible, and the use of drugs from the benzodiazepine group should be avoided, as they are characterized by prolonged release, especially in obese patients. After extubation, prophylactic bridging therapy with NIV, for instance, using CPAP, should be considered to prevent the need for re-intubation as well as reduce mortality, acute respiratory failure (ARF) and length of stay for patients in the ICU. NIV techniques are recommended in all extubated obese patients as they prevent the formation of areas of atelectasis [5]. In addition to the CPAP technique, HFNC can be effective in this group of patients to achieve a flow rate of 60 L/min at 100% inspired oxygen fraction (FiO_2) [7].

2.3 *Drug dosing in obese patients in ICU*

Obesity results in increased cardiac output, which plays a key role in the initial distribution of drugs. Increased blood flow through organs such as the liver and kidneys results in higher drug clearance. Additionally, there are differences in the blood supply of different types of adipose tissue, for example between visceral and subcutaneous fat, which can affect the pharmacokinetics of drugs. The effect of obesity on drug metabolism and clearance depends on specific metabolic pathways. For example, enzymes such as cytochrome P450 3A4 show decreased activity, while others such as 2D6, 2E1, 1A2 and 2C9 have increased clearance in obese individuals. Additionally, increased fat mass leads to an expansion of the volume of distribution of lipophilic drugs. The central volume of distribution, which includes blood and well-circulated organs, plays a key role in determining the saturating dose. Therefore, when dosing drugs in obese patients, physicians used to give higher initial saturating doses [17].

Choosing the right dose in obese patients remains a challenge. Many practicing intensivists face the dilemma of whether, and if so, which drugs require an increase in dosage due to the larger volume of distribution of the drug in obese patients. Despite the marked prevalence of the problem of obesity, there is still not enough data on this topic. Based on the few available publications, some conclusions can be drawn:

Propofol is a widely used sedative to support mechanical ventilation, mainly due to its rapid onset of action and short duration of effect. Although some studies suggest the use of propofol doses based on actual body weight (ABW), the relationship between body weight and pharmacokinetic variables, such as clearance, is not linear. The use of ABW-based doses may lead to excessively high drug concentrations in the blood. Therefore, dosing based on ideal body weight (IBW) or adjusted body weight is recommended. When dosing etomidate in obese patients with a BMI below 40 kg/m², it is recommended to use actual body weight (ABW). For patients with more advanced obesity (BMI ≥ 40 kg/m²), dosing based on adjusted body weight or ABW is recommended. For dexmedetomidine, dosing based on IBW or adjusted body weight is suggested. The use of ABW to calculate bolus doses or infusion rates may lead to excessive drug concentrations in the blood. In individuals with obesity, the volume of distribution for thiopental is increased, and its elimination half-life is prolonged. Considering that obesity is linked to higher cardiac output, it is unsurprising that the total clearance of thiopental is greater in obese individuals compared to lean ones. However, when adjusted for total body weight, thiopental clearance does not differ between obese and lean subjects [18].

Fentanyl has a large volume of distribution, which is related to its lipophilic properties. This volume is increased in obese patients, but the lower plasma concentration of fentanyl in the initial phase of distribution is mainly due to higher cardiac output. Fentanyl clearance is increased in obese patients and shows a stronger correlation with lean body weight (LBW; LBW = TBW - fat mass, although in obese patients, dedicated formulas are advisable) or IBW than with total body weight (TBW). For this reason, fentanyl dosing should be based on LBW or IBW. Similar conclusions can be drawn for remifentanil. The use of TBW-based doses can lead to substantially higher plasma concentrations. Therefore, remifentanil dosing in obese patients should be carefully adjusted, with a preference for LBW or IBW as the basis for calculations. Additionally, the volume of distribution and elimination half-life of sufentanil increase with obesity, but its clearance remains similar to that of normal-weight patients. Therefore, there is no contraindication to the use of TBW in this case [17, 18]. In one study, it was observed that the clearance of active metabolites of morphine was lower in obese subjects compared to healthy volunteers of normal weight. This may have important consequences with long-term morphine use [18].

Succinylcholine is currently the only non-depolarizing neuromuscular blocker used in clinical practice. In obese patients, pseudocholinesterase levels are elevated, requiring dose adjustments to achieve optimal intubation conditions. Studies indicate that a dose of 1 mg/kg TBW is most appropriate for morbidly obese patients, ensuring successful intubation. Rocuronium, an amino-steroid neuromuscular conduction blocking agent, shows no change in pharmacokinetics despite increased extracellular fluid volume in obese patients. Comparative pharmacokinetic and pharmacodynamic studies showed no differences in volume of distribution, clearance, mean residence time, and half-lives of distribution and elimination between obese and normal-weight subjects [18]. Nevertheless, it is recommended that rocuronium be dosed based on IBW. The available data on the use of cisatracurium in obese patients are somewhat limited. Research conducted across various patient groups, considering factors such as type of anesthesia, age, gender, creatinine clearance, and the presence of obesity, has revealed some differences in the effects of cisatracurium. However, these differences do not markedly alter the recovery profile, although they may influence the onset timing of the neuromuscular block. [19]. For non-depolarizing neuromuscular conduction blockers, evidence suggests that IBW, corrected body weight or lean body mass are the most appropriate indicators for use in weight-based dosing regimens in obese patients, particularly in those with more advanced forms of obesity (e.g., BMI ≥40 kg/m^2) [20].

Residual neuromuscular block can be particularly dangerous in obese patients. Hence, the use of antagonists of neuromuscular conduction blocking agents is often necessary. Studies show that the dose of neostigmine can be safely calculated based on TBW. [6, 19]. Sugammadex is an agent that allows rapid and complete reversal of neuromuscular blockade without causing the side effects associated with neostigmine. However, there are inconsistencies regarding the appropriate dosing approach for this drug in obese patients, especially in the context of choosing between TBW and IBW. Although different dosing approaches are recommended, recurrence of neuromuscular blockade has been reported in some cases, prompting the consideration that dosing should be based on ABW to ensure full reversal of neuromuscular blockade [17].

Table 2. Recommended dosage of drugs in patients with morbid obesity [6, 17, 18, 19, 20]

Drug	Dose
Analgesia	
Fentanyl	IBW or LBW
Remifentanyl	IBW or LBW
Sufentanyl	TBW
Morphine	IBW
Oxycodone	5 mg IV every 4h
Lignocaine	TBW
Paracetamol	IBW
Metamizole	No data, drug withdrawn in the United States
Neuromuscular blockade	
Rocuronium	IBW
Succinylcholine	TBW
Sugammadex	TBW
Cisatracurium	IBW
Neostigmine	TBW
Sedation	
Propofol	TBW
Etomidate	TBW, adjusted body weight for patients BMI ≥ 40 kg/m^2
Dexmedetomidine	IBW
Thiopental	TBW
Midazolam	TBW in initial dose, IBW in maintenance dose
Ketamine	IBW
Antiemetic	
Ondansetron	8 mg iv
Anticholinergic	
Atropine	No data
Ions	
Magnesium	No data
Calcium	No data

TBW – total body weight; IBW – ideal body weight; IBW = 22× (height in meters)^2; LBW – lean body weight; LBW = TBW – fat mass, in obese patients dedicated formulas or online calculators are advisable; Adjusted body weight; if the actual body weight is greater than 30% of the calculated IBW, there is need to calculate it from the formula: Adjusted body weight = IBW + 0.4 (actual weight – IBW).

However, the most important factor in decision making is to be guided by clinical premises. The above information can only provide a reference point.

2.4 *Sepsis*

Some studies indicate that sepsis mortality in obese patients is comparable or lower than the average population [21, 22]. Currently, retrospective studies and meta-analyses do not show differences in mortality in both groups of patients [21, 23]. A possible explanation for the protective effect of obesity is:

• Elevated lipoprotein levels can deactivate sepsis mediators and liposaccharides [24].

• In the catabolic phase, a large amount of adipose tissue constitutes a metabolic reserve.

• Adipose tissue increases the activity of the renin-angiotensin system. It may lead to hemodynamic stabilization in patients in shock.

Surviving Sepsis Campaign guidelines do not specify standards of care for obese patients. In the initial management of shock, it is recommended to infuse fluids in a volume of 30 ml/kg in the first 3 hours. However, it has not been specified whether 30 ml/kg refers to ideal, actual, or lean body mass [25].

Another problem is the dosing of basic drugs in this group of patients. With an increased volume of distribution, it may be necessary to increase the doses. Unfortunately, there is not enough convincing data on how or if doses of drugs should be increased. Table 3 presents the suggested procedure based on the available literature.

Table 3. Drug doses during sepsis in obese group of patients [6, 19, 20, 21, 23, 25, 26, 27, 28, 29]

Drug	Dose	Comment
Anticoagulants		
Enoksaparin	LBW	
Heparin	Dose under control of APTT	Check APTT
Antiarrhythmics		
Amiodarone	No data, under control of clinical effect	Drug concentration monitoring
β blockers	IBW then in correlation with clinical effect	
Diltiazem	IBW then in correlation with clinical effect	
Werapamil	IBW then in correlation with clinical effect	
Digoxin	IBW	
Antibiotics and Antifungal Drugs		
Vankomycin	TBW	Drug concentration monitoring
Carbapenems	Maximal available dose	Drug concentration monitoring

Table 3 contd.

Drug	Dose	Comment
β-lactams	IBW + 0.3 x (TBW-IBW)	Drug concentration monitoring
Ciprofloxacin	IBW + 0.45 x (TBW-IBW)	
Linezolid	No data	
Tigecycline	No data	
Amfotericin B	TBW	
Fluconazole	TBW	
Other Drugs		
Trombolitics	TBW in maximal available dose	
Corticosteroids	IBW	
Catecholamine	In correlation with clinical effect	

TBW – total body weight; IBW – ideal body weight; IBW = 22× (height in meters)^2; LBW – lean body weight; LBW = TBW – fat mass, in obese patients dedicated formulas or online calculators are advisable.

3. The obesity paradox in patients in intensive care units

Obesity is usually associated with an increase in mortality due to multimorbidity (higher incidence of diabetes, hypertension and coronary artery disease). However, taking into account the available literature, obesity may have a protective effect and reduce mortality in the ICU compared to the group of normal weight or overweight patients, which appears counterintuitive [6, 22, 27]. Additionally, as mentioned earlier, obesity is associated with a higher risk of ARDS, which is particularly relevant in the context of mechanically ventilated patients. However, it has been shown there are a lower amount of pro-inflammatory cytokines in obese people with ARDS than non-obese people suffering from ARDS. This would suggest that chronic inflammation induces a ‘tolerance’ to acute events such as ARDS. Additionally, increased adipose tissue plays a role in providing an energy reservoir to better withstand catabolic reactions during the course of severe disease during ARDS. Furthermore, it should be noted that morbidly obese patients are often admitted to the ICU for improved diagnostic and therapeutic conditions in a baseline better clinical condition compared to non-obese patients. Moreover, it has been documented that areas of atelectatic lung tissue can imitate bilateral inflammatory infiltrates in ARDS, thus leading to misdiagnosis [7]. Pickkers et al., in a cohort study on more than 154,000 critically ill patients, proved the obesity paradox after considering several factors, including, most importantly, the severity of the disease [30]. Conversely, the above study does not prove decreased mortality in non-obese patients in critical condition if they were obese. This may allow the sense of the obesity paradox to be questioned. [31].

Limitations of the study

Limitations of the present study may be due to the BMI cut-off that the authors of the studies assumed for the definition of morbid obesity, as, despite the definition, some authors selected study groups with a BMI ≥ 35 kg/m^2. In addition, the studies used included groups of patients who were generally degreed as 'obese'. Another limitation seems to have been the difference in the clinical status of the patients studied. Although the study groups were hospitalized in the ICU, the reason for admission and baseline condition may have been different. Furthermore, it should be taken into account that the size of the study groups in the source studies often differed, which allows the assumption that with a larger study group, the results might have been different.

Conclusions

Morbidly obese patients, due to their anatomical peculiarities and tendency to desaturate rapidly, are at risk of difficult intubation. Because of that, they should be intubated with video laryngoscopes in a ramped position and preoxygenated using NIV methods. In addition, a number of changes in the respiratory system, such as a tendency to form atelectasis, necessitate mechanical ventilation in the sitting position and the use of a RM and lung-sparing ventilation. Increases in adipose tissue and decreases in free water compartment and disorders in multi-organ homeostasis result in changes in distribution volumes and metabolism of many drugs, forcing the use of distinct dosing models. Clinicians should be aware of the risk of developing potentially fatal conditions threatening hospice patients in the ICU and to be ready to implement appropriate management. It is noteworthy that, despite the apparently poor prognosis of morbid obesity complicated by multimorbidity, this group of patients treated in the ICU does not have an expected higher mortality compared with non-obese patients. This potentially protective property of excessive body weight is explained by the phenomenon of the 'obesity paradox'.

In addition to the problems described above posed by morbidly obese patients in intensive care units, it is worth noting the other difficulties, not previously described in the content of the article, faced by medical staff in all hospital wards. Morbidly obese patients pose a greater challenge in daily care for the nursing team [32]. Additionally, standard ICU procedures such as vascular cannulation, including central access insertion or bladder catheterization, can be complicated in this patient group [33, 34].

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