Chapter

Ventilation Strategies in Obese Patients

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Abstract

Obesity is an increasingly prevalent disease and is a root and complication of conditions necessitating mechanical ventilation. Obese patients require a careful approach due to the particular manner of how ventilatory mechanics is affected, if obstructive sleep apnea (OSA) is present. The two main diagnoses we may encounter while ventilating these patients are obesity hypoventilation syndrome (OHS) and chronic obstructive pulmonary disease (COPD) in an obese patient, which has been recently proposed as a novel phenotype of COPD. The excessive amount of fat in the abdomen, chest wall, and around upper airways warrants the use of special ventilation modes and settings. This chapter provides insight into which issues should be considered when ventilating an obese patient, either in acute or chronic conditions. We stress the importance of acknowledging the high risk of OSA and how OSA affects the ventilation algorithms.

Keywords: non-invasive ventilation, obesity hypoventilation syndrome, COPD, overlap syndrome, sleep-disordered breathing, ventilation strategies

1. Introduction

Obesity is a disease with prevalence increasing significantly; about a third of the world's population is overweight or obese. The number of obese people has doubled in the last 20–30 years, and this trend continues [1]. This is closely related to the increase in the number of obese patients admitted to the intensive care units (ICU) as well as those requiring mechanical ventilation. The specificity of obesity in critically ill patients lies in the increased risk of infections, impaired respiratory drive, respiratory mechanics as well as the presence of sleep-disordered breathing [2]. A frequently mentioned diagnosis linking respiratory failure and obesity is obesity hypoventilation syndrome (OHS), but obesity also affects patients with other diseases, including respiratory and lung diseases. It is necessary to mention patients with chronic obstructive pulmonary disease (COPD), where a subset of obese patients benefits from a different approach to diagnosis and treatment compared to low-weight patients. This chapter aims to clarify the issue of respiratory failure in obesity and its treatment using mechanical ventilation in both acute and chronic conditions.

2. Mechanisms of respiratory failure development in obesity

The development of respiratory failure in obesity is a gradual and often long-term process. Although the proportion of individual factors may vary from patient to patient, the disease results from a complex of the following mechanisms [3–6]:

- Reduction of vital capacity and functional residual capacity due to the mass of abdominal and subcutaneous chest fat
- Upper airway narrowing and collapse during sleep—obstructive sleep apnea (OSA)
- Accumulation of fat deposits in the respiratory system with increased lower airways resistance
- Increased work of breathing (increased respiratory load)
- Hypoxic pulmonary vasoconstriction
- Fluid overload associated with nocturnal rostral fluid shift
- Rapid eye movement (REM) associated hypoventilation
- Impaired respiratory mechanics—muscle weakness
- Central leptin resistance—deterioration of the respiratory drive
- Accumulation of serum bicarbonate—reduction of ventilatory response to carbon dioxide (CO_2)

All these pathomechanisms affect the development and course of the disease in individual patients and should be considered in the diagnosis and treatment of respiratory failure and the setting of ventilation strategies. Guideline for mechanical ventilation generally distinguishes recommendations for the treatment of patients with obstructive pulmonary disease and restrictive diseases and separately for the diagnosis of obesity hypoventilation syndrome [7–9]. However, as obesity is present in various diseases and the above-mentioned pathomechanisms contribute to the clinical picture, in the following, we will mention the specifics of the treatment of respiratory failure in multiple diseases.

3. Obesity hypoventilation syndrome

Obesity hypoventilation syndrome is standardly defined by the combination of:

- Obesity with body mass index (BMI) ≥ 30 kg m^{-2}.
- Daytime hypercapnia—arterial CO_2 tension ($PaCO_2$) ≥ 45 mm Hg.
- Sleep-disordered breathing.
- The diagnosis of OHS cannot be made if an alternative explanation for hypoventilation (e.g., neuromuscular, mechanical, or metabolic disease) is present [10].

As the development of hypoventilation in OHS is gradual, the diagnosis is in most cases made at a stable stage, when the patient is examined in a sleep laboratory for symptoms of sleep-disordered breathing [10]. Approximately one-third of patients are diagnosed at the point of acute-on-chronic hypercapnic respiratory

failure [11], and these patients often require critical care. Comorbidities such as heart failure (usually with preserved ejection fraction), pneumonia, and sepsis contribute to the acute condition. A major problem in the acute and long-term management of these patients is that instead of making a correct diagnosis of OHS, other diseases such as COPD or asthma are misdiagnosed [12, 13]. The misdiagnosis of obstructive pulmonary disease without adequate lung function examination incorrectly directs treatment to the application of bronchodilators instead of adequate respiratory support.

3.1 Classification of OHS patients

Based on the presence of OSA and hypoventilation, three phenotypes of patients with OHS were observed [14, 15]:

- **Severe OSA**—free of REM sleep hypoventilation. This phenotype is characterized by a lack of CO_2 washout capacity after obstructive apnea episodes.

- **Isolated OHS**—characterized by morbid obesity (BMI often ≥40 kg m^{-2}), severe hypercapnia and REM sleep hypoventilation without the presence of OSA.

- **Combined OHS and OSA**.

Polysomnographic (PSG) findings for individual phenotypes are shown in **Figure 1**.

Figure 1 describes the excerpts of polygraphic recordings displaying from the top oxygen saturation, thoracic respiratory effort, airflow, and snoring. The first excerpt of severe OSA is exhibiting short interapneic intervals with oxygen saturation rising above 90%. The second excerpt illustrates low baseline oxygen saturation with further desaturations after apneic events. The third excerpt shows low baseline saturation with no desaturations reflecting isolated hypoventilation.

The classification is based on observations and medical evidence. It is a fact that a significant proportion of patients with OHS have concomitant OSA (near 70%

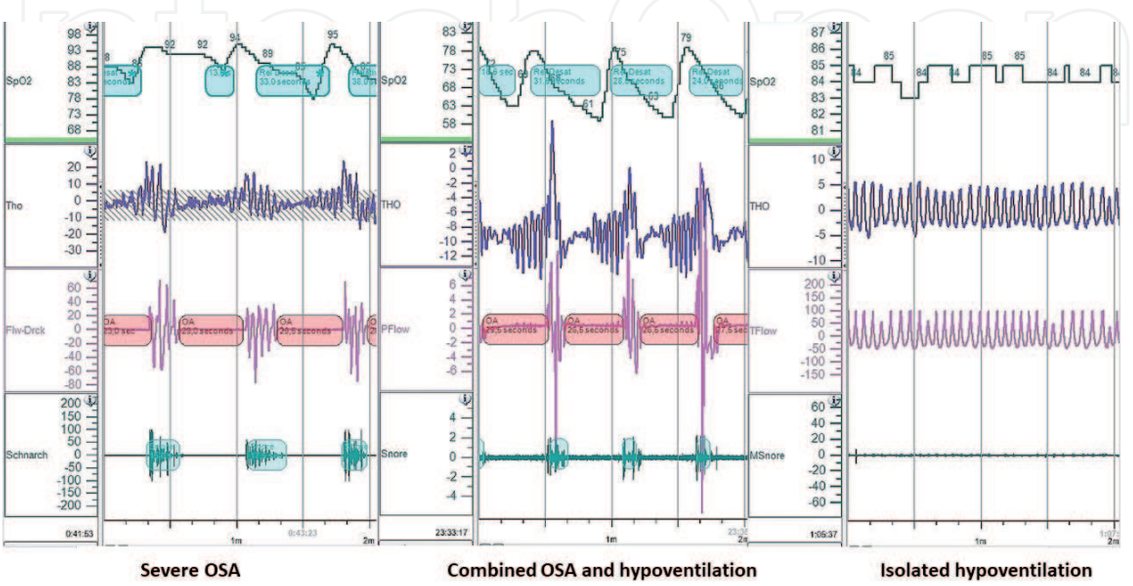

Figure 1.
Phenotypes of OHS.

of patients have severe OSA), and its presence should be presumed in treatment, especially in acute situations [14]. In a stable state, it is appropriate to devote time to the precise diagnosis, differential diagnosis, and titration of treatment.

3.2 Ventilation strategies in acute hypercapnic respiratory failure and OHS

While continuous positive airway pressure (CPAP) treatment may be appropriate for OHS and chronic hypercapnic respiratory failure, noninvasive ventilation (NIV) is the method of choice for acute or acute-on-chronic respiratory failure. It is a better alternative to invasive ventilation because it significantly reduces patient morbidity and mortality and reduces the risk of reintubation [7, 15].

3.2.1 Indications for NIV in acute hypercapnic respiratory failure in OHS

In an obese patient with a known or suspected diagnosis of OHS who meets the criteria for initiating ventilation support, noninvasive ventilation should be considered the first treatment modality.

Acute ventilatory support in OHS patients is indicated if the following criteria are met [16]:

- $PaCO_2 \geq 45$ mm Hg.
- Respiratory acidosis with $7.1 < pH < 7.35$.
- Severe breathlessness, tachypnea (≥23 breaths per min).

3.2.1.1 Notes

- Severe respiratory acidosis increases the risk of NIV failure but is not an obstacle to this treatment. It is possible to start a trial with NIV and be prepared for urgent endotracheal intubation.
- NIV can also be indicated in some hospitalized obese hypercapnic patients with daytime somnolence, sleep-disordered breathing, and/or right heart failure in the absence of respiratory acidosis [17].

3.2.2 Examinations and procedures before the start of the NIV

Before starting treatment with NIV, it is necessary (assuming patient safety—no delay of NIV) to perform the following procedures:

- Blood collection for arterial blood gas (ABG) analysis. An arterialized capillary blood sample (e.g., by heat) is an alternative
- Electrocardiography (12 lead)
- Chest radiography
- Search for and treatment of reversible causes of respiratory failure
- To determine in advance an individual plan for possible escalation of treatment (e.g., for do not intubate patients) [17]

3.2.3 Management of NIV in acute OHS patient

In the case of acute OHS, the NIV should be started immediately. OHS patients with severe daily sleepiness may be so somnolent that they cannot participate in placing their face masks. Treatment should be provided by staff experienced in NIV, and the patient should be placed in a high dependency unit (HDU) or intensive care unit (ICU) for close monitoring [17].

3.2.3.1 Important notes on the management of acute NIV in OHS

- **Interface**—Face mask (oronasal/full-face mask) is preferred in acute settings and very obese patients because of high pressures and mouth breathing [15]. Proper mask fitting is the key to successful NIV. It is advisable to choose the appropriate size mask (masks too large for the patient's face are more likely to leak) and adjust the restraining straps so that the mask is so loose that it seals well. In the case of skin lesions or bruises with an oronasal mask, it is possible to try the rotation of the masks (regular alternation of different masks; for example, total face mask or under nose full-face mask—e.g., Amara view, Dreamwear full-face—Philips Respironics™).

- **Ventilation mode**—Ventilation modes with backup respiratory rate are recommended in acute settings, for example, spontaneous-timed (ST) or pressure controlled (PC) mode, depending on the ventilation device and physician's experience.

- **Expiratory positive airway pressure (EPAP)/positive end-expiratory pressure (PEEP)**—It should be at least 8 cm H_2O [7, 15, 17]. It is possible to start with pressure 6 cm H_2O and gradually titrate upwards to improve tolerance and oxygenation, reduce respiratory load and control upper airway obstruction (snoring reduction). EPAP higher than 13–14 cm H_2O can be poorly tolerated, and too high EPAP reduces the possibility of achieving sufficient pressure support (depending on the ventilation device). Since comorbid sleep apnea is present in sleep, it is necessary to optimize EPAP during sleep. Software analysis of ventilation is helpful in subsequent parameter adjustments. Effective EPAP can be titrated manually, alternatively using specific modes, for example, AVAPS-AE™ (Philips Respironics) or auto-ST (Löwenstein medical) [18].

- **Inspiratory positive airway pressure (IPAP)**—It should be initiated at least 8 cm H_2O higher than EPAP. The difference between EPAP and IPAP, that is, pressure support (PS), should be increased gradually (up to 30 cm H_2O) to achieve a sufficient chest wall excursion and tidal volume (measured or estimated by a ventilator), but patient tolerance must be achieved [11, 15, 16].

- **Ensuring the target volume**—The use of ventilation pressure-controlled modes with target tidal volume settings such as average volume assured pressure support-AVAPS™ (Philips Respironics) or target volume (Löwenstein medical) is not necessary. However, in extremely obese patients with marked respiratory asynchrony in NIV, these modes can be used, as the ventilator can compensate for changes in lung compliance (e.g., patient position changes or tidal volume variability in-breaths triggered spontaneously or by device). Target tidal volume should be calculated and targeted at 8 (maximum 10) mL kg^{-1} ideal body weight [15]. PS (IPAP settings—IPAP

minimum-maximum) should be in an acceptable range (starting 4 cm H_2O above EPAP) to allow the device to reach the desired tidal volume. The rate of pressure change (to adjust tidal volume) is suitable to choose medium to fast. Volume-targeted ventilation modes are accompanied by higher mask air leaks but can (assuming good mask fitting) improve breathing synchronization instead of changing to other modes.

- **Backup rate**—Setting the backup respiratory rate in the range of 12–14 is the prevention of central apnea and hypoventilation during sleep [19].

- **Inspiratory time**—For mandatory breaths should be at least 1.2 s (up to 1.5 s). For ventilation devices with the possibility of setting the inspiratory and expiration ratio (I-E ratio), it is suitable to set it 1:2–1:1 [20].

- **Oxygen**—Oxygen inhalation is an extreme risk for OHS patients as it worsens hypoventilation [21]. In the stable and acute stage, oxygen is considered an additional treatment to NIV. In acute NIV, the amount of oxygen must be increased gradually to achieve saturation above 90% [11, 14–16].

- **Forced diuresis**—In acute-on-chronic respiratory failure in OHS, fluid overload commonly contributes to the severity of the disorder. Forced diuresis may be helpful initially [17].

- **Phlebotomy**—Hyperviscosity associated with secondary erythrocytosis may impair oxygen delivery in OHS patients. Phlebotomy may be considered in a patient with very high hematocrit as a part of intensive care therapy, provided that NIV is treated effectively and with sufficient oxygenation [11].

3.2.3.2 Contraindications to the use of NIV

Absolute:

- facial burns, severe facial deformity—inability to put on a mask
- gastrointestinal bleeding or ileus
- significant hemoptysis
- undrained pneumothorax
- inability to protect the airway, for example, fixed airway obstruction

Relative:

- copious respiratory secretions
- hemodynamic instability (cardiogenic shock, myocardial infarction)
- severe hypoxemia and acidosis (pH < 7.1)—predictors of NIV failure
- confusion/agitation
- coma—however, hypercapnic coma can be reversed using NIV [22, 23]

3.2.3.3 Monitoring in acute NIV

Patients treated with NIV require intensive care and careful monitoring, including:

- Monitoring: Respiratory rate, oxygen saturation, end-tidal CO_2, blood pressure, transcutaneous measurement of carbon dioxide ($TCCO_2$)
- Observation: Dyspnea, paradoxical abdominal movements, mask leaks, asynchrony with ventilator
- Measurements: Glasgow coma scale (GSC), acute physiology and chronic health evaluation (APACHE) score
- Labs: Blood gas analysis (sampling after 1–2 h of NIV, followed by 6–12 h for the first 24 h)
- Waveforms: Analysis of NIV parameters [23]

3.2.3.4 Failure of acute NIV and indication of endotracheal intubation in OHS

Despite careful monitoring and proper ventilation, NIV failure may occur in some cases. There is no exact algorithm to determine when to indicate intubation, but it is necessary to know the most common predictors of NIV failure [23–25]:

- excessive unintentional air leaks
- high severity score on admission (pH < 7.25, APACHE II score > 29)
- excessive respiratory secretions
- intolerance and noncompliance with NIV
- polymorbidity
- severe hypoxemia and low level of $PaCO_2$
- pneumonia
- low level of bicarbonates (HCO_3)—possible link to renal failure
- short duration of NIV
- minimal or no change in pH after 1–2 h of NIV
- no reduction in respiratory rate after 1–2 h of NIV

3.2.3.5 Further recommendations after successful acute ventilation in OHS

Data show that patients with a diagnosed or suspected diagnosis of OHS have a higher risk of death if they are discharged from the hospital without home positive airway pressure (PAP) treatment. Therefore, it is appropriate to set these patients for NIV treatment (ideally with pressure settings as in

hospitalization or with auto-PAP settings) and to schedule an early examination in the sleep laboratory and titration of PAP treatment (within 3 months) [26]. In patients acutely ventilated invasively, the use of NIV is an appropriate weaning strategy, as it effectively prevents respiratory failure in the first 48 h after extubation [24]. In patients requiring tracheostomy for prolonged invasive ventilation, it is advisable to perform decannulation and adjustment to home NIV after successful weaning instead of indicating long-term mechanical ventilation via tracheostomy.

3.3 Ventilation strategies in chronic hypercapnic respiratory failure and OHS

Initiating treatment of OHS patients in a stable stage allows assessing the ventilation strategy carefully. The choice of appropriate treatment should be based upon the severity of clinical state, the laboratory, functional and polysomnographic findings, reasonable cost-effectiveness, and the physician's experience. Clinical practice and literature data do not favor treatment by either CPAP or NIV as they are comparable, though some studies acknowledge certain benefits of NIV over CPAP.

3.3.1 Comparison of effectivity of CPAP and NIV

In the medium-term treatment, both CPAP and NIV have improved:

- Daytime hypercapnia, sleepiness [27]
- Health-related quality of life [28]
- Polysomnographic measures [29]
- Structural and functional echocardiographic measures [30]

NIV was superior to CPAP in terms of:

- Lung functions and 6 min walking test
- The rapidity of blood gases improvement [28]

In the long-term treatment, both CPAP and NIV have improved:

- Number of hospitalization days [31]
- Pulmonary hypertension and left ventricular diastolic dysfunction [32]

The concerns about the potentially harmful effect of NIV of hemodynamics due to the application of unphysiological positive pressure have been addressed by utilizing impedance cardiography, but it has not shown any deleterious impact on ventricular function [33].

The one undeniable benefit of CPAP over NIV is its lower cost [34]. The novel guidelines for the management of OHS by the American Thoracic Society [26] propose a switch of treatment from NIV to CPAP once the patient has achieved significant clinical improvement. This switch has been shown to be feasible and even favored by patients [35].

3.3.2 Obstructive sleep apnea

The one defining feature of OHS is its high prevalence of OSA, mainly of severe degree (estimated in around 70% of OHS patients). Thus, in patients with an apnea-hypopnea index (AHI) cut-off ≥30 episodes/h, it is reasonable to start with CPAP, as the primary aim is to alleviate obstruction in the upper airways, which might lead to the eventual resolution of chronic hypercapnia. For the patients without severe OSA, we should aim to improve the mechanics in the respiratory system and depression of the respiratory center; that is why NIV is used as an initial treatment.

3.3.3 Failure of CPAP

The patients initially set on CPAP should be monitored for signs of CPAP failure. In that case, a switch to NIV is warranted. The definition of CPAP failure is inconsistent among different researchers. Some of the criteria used for CPAP failure in OHS patients were:

- Insufficient improvement of oxygen saturation on CPAP:
  - Oxygen saturation below 90% for more than 20% of total sleep despite adequate abolition of apneas and hypopneas [36]
  - Oxygen saturation < 85% or hypercapnia despite maximal CPAP [37]
  - Oxygen saturation below 90% for more than 30% of titration night [38]
  - Oxygen desaturation < 80% over 10 min [9]
- Persistence of apneic and hypopneic episodes [37]
- Insufficient improvement of CO_2 levels
  - ≥5 min-long increase in nocturnal $PTcCO_2$ > 55 mm Hg and in $PaCO_2$ ≥ 10 mm Hg compared to the awake state [9]
  - Daytime $PaCO_2$ > 45 mm Hg [38]

The choice of criteria for CPAP failure should be suited for the practice of a particular sleep laboratory, and it should be consistent over time.

Careful evaluation is necessary to avoid deeming inadequate patient compliance as CPAP failure.

It is important to note that a failure of CPAP during titration does not necessarily lead to failure of the CPAP treatment [36]. A single or few titration nights of CPAP may falsely display a failure, when in fact, a more extended period of treatment (2–3 months) might be necessary for CPAP to be effective. The length of a trial should be adapted according to the convenience of a sleep laboratory.

3.3.3.1 Predictors of CPAP failure

The high proportion of CPAP failure in OHS patients has led to identifying certain predictors when CPAP should be tried with a reasonable expectation of success and when to proceed straight to NIV.

Recognized CPAP failure predictors were:

- awake oxygen saturation < 94% and PaO_2 < 68 mm Hg [37]
- daytime $PaCO_2$ > 53 mm Hg [15]
- BMI ≥ 50 kg m^{-2} [15, 39]
- significant comorbidities [40]
- acute respiratory failure [39]
- and clinician's preference [39]

Generally, worse blood gases [38], higher obesity, significant comorbidities, and clinician's preference warrant the trial of NIV in the first step.

3.3.4 Setup strategies of NIV

Novel increasingly intelligent auto-titrating devices are able to adjust to a patient's ventilatory need depending on his/her body position or the sleep stage.

- Volume targeted pressure support assures sufficient ventilation but may potentially lead to sleep disturbance.
- Auto-titrating EPAP allows to maintain the patency of upper airways and alleviates concomitant sleep apnea [18].
- Standard ST mode is not inferior to the novel modes but requires precise and gradual titration, which is time-consuming.

Similarly, as the OHS patients are monitored for signs of CPAP failure, patients with NIV should be checked frequently, as there is a possibility of improvement of the respiratory center sensitivity, and a switch from NIV to CPAP might be considered.

4. Chronic obstructive pulmonary disease (COPD)

COPD is a serious disease with an increasing prevalence, accompanied by a high risk of respiratory failure [41]. Unlike OHS, COPD is a disease where, in addition to the failure of the ventilatory pump (muscle weakness, shortening of the diaphragm), lung disease (obstructive airway disorder) is added [42]. The severity of the situation and the fact that it is a progressive disease also affect the management of respiratory failure. The use of NIV in COPD is common practice today. This treatment has clearly been shown to be effective in acute exacerbations of COPD (AECOPD) [43] and has long been a controversial topic in chronic indications [44]. However, recent studies have provided clear evidence in favor of treatment (including the effect on survival), and the greatest benefit of NIV has been present with higher pressures in NIV settings for maximum CO_2 reduction, in patients with higher basal $PaCO_2$ values, and in those who achieve high treatment compliance [45–47]. In the management of hypercapnic respiratory failure in COPD, there is growing evidence of the effectiveness of so-called high-intensity NIV (HI-NIV) [48].

However, many studies and guidelines perceive COPD as a single disease and do not reflect the existence of different phenotypes, comorbidities, and the need for a unique approach to them. One of them is an obese patient with COPD.

4.1 Obese patient with COPD

Several respiratory societies perceive COPD, not as a single homogeneous airway disease but also distinguishes between several phenotypes characterizing differences between patients [49, 50]. In intensive care units, patients with COPD often appear to be classified as a classic "Blue bloater." These patients are generally classified as chronic bronchitis phenotype, but its definition does not fully describe such a complex clinical trait. On the contrary, there is increasing evidence that this trait of COPD patients is characterized by different radiological findings than those seen in emphysema, and it is associated strongly with obesity and frequently also with OSA [51]. The prevalence of obesity among COPD patients is also very high and variable (18–54%) [51, 52]. Obesity is strongly linked with the presence of OSA, and in COPD patients requiring inpatient pulmonary rehabilitation, the number of obese patients with OSA increases significantly [53]. The presence of obesity and the COPD-OSA overlap syndrome appears to be a key factor in the pathogenesis and development of clinical signs of the blue bloater trait. This statement is underlined with evidence that the severity of static hyperinflation is negatively associated with the apnea-hypopnea index in both COPD and non-COPD patients surviving acute hypercapnic respiratory failure [54]. This evidence is following data showing that overlap syndrome increases the risk of respiratory failure, pulmonary hypertension, and COPD exacerbations [55]. In line with the above literary data [56], a new "obese patient with COPD" phenotype (characterized by predominantly chronic bronchitis, less hyperinflation, metabolic and cardiovascular comorbidity, sleep apnea symptoms, that is, daytime sleepiness, snoring, nonrefreshing sleep, and/or hypercapnic respiratory failure) was proposed [57] with a recommendation of screening for sleep-disordered breathing in this group of patients [50].

4.2 Ventilation strategies in acute exacerbation of COPD in obese patients

Acute exacerbation of COPD (AECOPD) is a severe condition that requires urgent intervention, and recommendations for its treatment are well known [41]. NIV has an irreplaceable place in the management of AECOPD in the event of acute or acute-on-chronic respiratory failure [17, 43]. In a patient with COPD who is obese, it should be borne in mind that obesity is probably one of the predominant factors predisposing to respiratory failure. Other possible factors such as cardiogenic edema, infection, uncontrolled excessive oxygen therapy, or pneumothorax should not be forgotten [17]. Because NIV effectively prevents endotracheal intubation and survival in patients with AECOPD [23, 58], it should be indicated whenever a patient meets the criteria for initiation.

4.2.1 Indications for NIV in acute hypercapnic respiratory failure in COPD

Acute ventilatory support in AECOPD is indicated in the same criteria as in OHS patients:

- $PaCO_2 \geq 45$ mm Hg
- Respiratory acidosis with $7.1 < pH < 7.35$
- Severe breathlessness, tachypnea (≥23 breaths/min)

4.2.1.1 Notes

It should be emphasized that controlled low-flow oxygen therapy (to achieve a saturation of 88–92%) is the basis for treating respiratory insufficiency in COPD. However, if respiratory acidosis develops or progresses (pH < 7.35) during careful monitoring of this treatment, NIV is recommended [7, 23].

4.2.2 Examinations and procedures before the start of the NIV

Examinations before the start of NIV are recommended the same as in Section 3.2.2. A chest radiograph is necessary to determine whether the deterioration of the patient's condition is caused by pneumothorax or pulmonary edema.

4.2.3 Management of NIV in an obese patient with AECOPD

A patient with AECOPD with respiratory acidosis is at extreme risk of early death, and early intervention is necessary [59]. NIV is highly effective in this indication but does not replace the standard treatment of AECOPD, which must be given in each case. NIV should be started as soon as it is confirmed that regulated oxygen therapy is failing. In the case of AECOPD, as in the case of OHS, CPAP is not an appropriate treatment (as respiratory support). The method of choice is bilevel ventilation [7, 17, 23]. In treating obese patients with COPD, we can generally proceed from the procedures in OHS, with certain specifics for airway disorder.

4.2.3.1 Important notations on the management of NIV in obese patients with AECOPD

- **Interface**: Since mouth breathing predominates in AECOPD, we prefer the oronasal (full-face) mask. Prevention of skin lesions is necessary, and mask rotation is useful. In case of failure to use the mask, helmet ventilation may be a suitable alternative.

- **Humidification**: Humidified ventilatory circuits are necessary for patients with airway disease.

- **Ventilation mode**: Spontaneous-timed (ST), pressure-controlled (PC) mode, allowing you to set the backup frequency.

- **EPAP**: For COPD, it is standardly recommended to set EPAP to exceed intrinsic PEEP in the airways (usually 5–6 cm H_2O). Because obese patients with COPD have a high risk of OSA, it is necessary to proceed as in the diagnosis of OHS and increase EPAP to eliminate upper airway obstruction (which is a condition for successful NIV).

- **IPAP**: The inspiratory pressure settings are like those in an acute patient with OHS. The purpose is to ensure sufficient pressure support, unloading of respiratory muscles, and reduction of respiratory work. It is necessary to achieve the required tidal volume, chest excursions, decrease respiratory rate, and eliminate the diaphragmatic paradox. IPAP can start at 15 cm H_2O, titrates upwards gradually in the range of 20–30, which are commonly used to manage AECOPD (mostly in pH < 7.25) [17, 44, 60]. However, patient tolerance is fundamental, and pressure increases must be gradual and monitored.

- **Ensuring the target volume**: Using ventilation pressure-controlled modes with target tidal volume settings can be useful, well-tolerated, and effective in managing AECOPD in obese patients. In addition, from a practical point of view, in an acute state, automatic modes (e.g., AVAPS™, target volume) require less intervention by staff (in terms of parameter titration) than in simple bilevel modes. In COPD, tidal volume can be targeted at 6 (maximum 8) mL kg^{-1} ideal body weight [60]. The rate of pressure change (to adjust tidal volume) is suitable to choose medium to fast (in super-obese patients).

- **Backup rate**: Backup respiratory rate should be set at 15 breaths/min [23].

- **Inspiratory time**: For mandatory breaths, 0.8–1.2 s according to breathing frequency. I-E ratio can be set 1:2–1:3 [20, 23]. For ventilators with the possibility of setting the inspiratory ramp and rise time, it is advisable to set them so that the patient has enough time to inhale and, in the case of prolonged expiration, allow him/her to exhale effectively.

- **Oxygen**: Standardly added to the ventilation circuit to achieve a saturation of 88–92%.

- **Monitoring choices and contraindications to NIV** are the same as in OHS (Section 3.2.3).

4.2.3.2 Failure of acute NIV and indication of endotracheal intubation in AECOPD

Predictors of NIV failure have already been mentioned in Section 3.2.3. The documented percentage of NIV failure ranges widely from 5 to 40% (depending on the predictors of failure, patient selection, and staff experience with NIV). Analysis of several studies has shown that the most significant predictor of NIV failure is pH 1 h after the onset of NIV, followed by the severity of the underlying disease and patient compliance [61]. If the pH after 1–2 h of NIV is below 7.25, respiratory rate > 25/min, or new confusion or distress appears, consider intubation [17]. Nevertheless, if NIV adds to patient distress and intubation has been inappropriate, NIV should be discontinued, and palliative care measures adopted [17].

In case of NIV failure and planning for escalation of treatment to invasive mechanical ventilation (IMV), it is necessary to [23, 60]:

- monitor and document parameters and signs indicating intubation

- document and provide a decision in "do not intubate" patients

- discuss the management with the patient and family

- plan intubation before late failure of NIV

4.2.4 Further recommendations after successful acute ventilation in COPD

NIV may be an appropriate option in patients who have survived intubation and invasive mechanical ventilation and require continued treatment for chronic respiratory failure. However, in ventilator-dependent patients requiring ventilation for 12 h or more, tracheostomy may be considered and is highly recommended if

the ventilation time exceeds 16 h per day. In this case, it is necessary to provide a ventilation device with an integrated battery [17, 40]. There are at least two reasons why we can assume that patients who have survived AECOPD with a need for NIV or IMV will be candidates for long-term home ventilation. The first is that obese patients with COPD have probable or known sleep-disordered breathing and will require some form of PAP treatment [53, 56]. Secondly, an episode of acute hypercapnic respiratory failure (AHRF) is a milestone in the course of the disease that predicts adverse development and prognosis [17]. In contrast to OHS (where weight reduction can reverse the course of the disease), this fact supports the planning of long-term ventilation treatment in obese patients with COPD. Therefore, clinicians should discuss the management of possible future episodes of AHRF with patients following an episode requiring ventilatory support because there is a high risk of recurrence [17]. Timing of indications for home mechanical ventilation (HMV) in COPD is a debated topic and ultimately depends on the decision of the patient and the physician. If the patient's condition after AHRF is stable, does not require continued ventilation, he/she may be discharged from the hospital with a scheduled early follow-up. It is recommended to reassess postacute NIV COPD patients 2–4 weeks after clinical recovery. NIV should be considered if the pCO_2 remains >7 kPa (53 mm Hg) [47] or if sleep-disordered breathing is detected in a sleep study.

4.3 Ventilation strategies in stable obese COPD patients

COPD is a disease associated with a high risk of developing chronic respiratory insufficiency [41]. Despite long-standing discussions about whether long-term NIV can affect the course and prognosis of the disease, the reality is that more than a third of patients treated are patients with lung and airways diseases [62]. Moreover, we now know that long-term NIV positively affects the quality of life and symptoms and improves survival [46, 47]. Thus, the question is not whether to ventilate COPD patients, but which COPD patients benefit from NIV and when it should be initiated.

4.3.1 Overlap syndrome COPD-OSA

Obese patients with COPD are very likely to have OSA simultaneously, commonly referred to as overlap syndrome [63]. The prevalence of these diseases in the general population is up to 10%, but in severely ill patients with COPD, the prevalence of OSA may be much higher, especially in the obese [53]. The coexistence of both diseases leads to a combination of continuous hypoxia (due to COPD) and chronic intermittent hypoxia (during sleep in apnea episodes due to OSA) in patients, which contributes to the development of the described clinical phenotype (Section 4.1) [57]. CPAP is the standard treatment for OSA and overlap syndrome [64]. However, CPAP treatment alone is more suitable for normocapnic patients with COPD, as it may not be effective in reversing hypoventilation and hypoxemia. Options should be carefully considered, and if nocturnal hypoxemia persists despite CPAP treatment, NIV may be an appropriate treatment instead of adding oxygen therapy to CPAP. In COPD patients diagnosed with OSA in the sleep laboratory, CPAP has been shown to fail in more than one-fifth. Although there are no clear limits to the efficacy of CPAP, treatment failure and NIV indication are more common in patients who are more obese, have worse lung function, hypercapnia, and more severe hypoxemia (with a longer desaturation time below 90% during nocturnal PSG) [65].

4.3.2 Indications for NIV in chronic hypercapnic respiratory failure in COPD

There is not only one criterion for indicating long-term NIV in COPD, which is confirmed by common practice that patients need to be approached individually [7, 9, 44, 66]. Long-term NIV may be indicated at a stable stage of COPD or after overcoming an acute exacerbation, meeting specific criteria, and considering the patient's needs. An important factor influencing the decision on the need for NIV is the presence of OSA. Contrary to the diagnosis of OHS with severe OSA, in the case of COPD-OSA overlap and hypercapnia, CPAP is not an appropriate option. CPAP may be effective in normocapnia in this case, but in hypercapnic COPD and the likelihood of progression of the underlying lung disease, NIV is the treatment of choice.

Long-term NIV may be indicated in well-established COPD (treated according to guidelines) in which there are persistent symptoms of chronic hypoventilation (hypercapnia), **and at least one of the following criteria is met:**

- chronic daytime $PaCO_2 > 50$ mm Hg
- nocturnal hypercapnia with $PaCO_2 > 55$ mm Hg
- daytime hypercapnia with $PaCO_2$ 45–50 mm Hg and nocturnal rise in transcutaneous CO_2 ($PTCCO_2$) ≥ 10 mm Hg
- stable daytime hypercapnia with $PaCO_2$ 45–50 mm Hg and at least two hospitalizations for hypercapnic respiratory failure within the past 12 months
- overlap syndrome COPD-OSA and daytime hypercapnia with $PaCO_2 > 45$ mm Hg
- after overcoming an acute exacerbation, if the need for respiratory support persists (based on clinical estimation)

4.3.3 Examinations before the start of long-term NIV

Blood gas collection and chest X-ray are recommended as standard. If possible, it is advisable to carry out a sleep study, preferably with the measurement of transcutaneous capnometry. Finally, the examination of lung functions is critical. Although this is not indicated directly in COPD exacerbation, in patients with a controversial diagnosis (especially in an obese patient), a misdiagnosis of COPD is common. Planning spirometry and possible body plethysmography with a distance from exacerbation before setting for long-term NIV will make it possible to clarify the diagnosis and set up treatment effectively.

4.3.4 Management of long-term NIV

Because patients with COPD form a wide range of different phenotypes, making precise recommendations on setting long-term NIV is not easy. In recent years, various approaches have been used, including the so-called low-intensity NIV (LI-NIV) and high-intensity NIV (HI-NIV) [44, 66]. The main difference is that HI-NIV uses higher values of IPAP and backup frequency to achieve normocapnia [48]. This approach has been shown in clinical trials to be effective in improving symptoms and quality of life and even in improving survival [45–47]. NIV was most effective

in those COPD patients where IPAP over 18 cm H_2O was used, baseline $paCO_2$ was over 55 mm Hg, and NIV was used overnight for more than 5 h [44]. Another option is to use volume-targeted ventilation modes. In COPD, their use is equally effective compared to HI-NIV [67]. It can make sense to obese patients with COPD because they allow them to better adapt to current and later patient needs when set up correctly.

4.3.4.1 Important notes on the management of long-term NIV in obese patients with COPD

- **Interface**: The choice of mask for long-term NIV is at the patient's and the physician's discretion but must ensure adequate ventilation and low leakage (e.g., in mouth breathers).

- **Ventilation modes and pressure settings**: Spontaneous-timed (ST) is the best option for long-term NIV. Automatic modes can be used to titrate settings, especially EPAP. The pressure setting is similar to AECOPD; the aim is to ensure airway patency (eliminate obstructive apnea). IPAP titration in chronic respiratory insufficiency may be less steep than in acute conditions. We can start at IPAP 12 cm H_2O and gradually increase above 18 cm H_2O (often between 20 and 30). We titrate the backup frequency slightly higher than in OHS. However, the basis is to ensure patient tolerance and compliance. Target volume modes can be used in obese patients like in AECOPD.

- **Oxygen**: In hypercapnic COPD, inhalation of oxygen through a nasal cannula is risky due to the progression of hypoventilation. If the NIV alone is insufficient to maintain saturation above 90%, it is advisable to add oxygen to the ventilation circuit.

5. Conclusion

This chapter aimed to discuss different approaches to the treatment of respiratory failure depending on the situation and diagnosis in obese patients. Up-to-date information from evidence-based medicine and international guidelines was used in the preparation of the chapter. Although COPD and OHS are different diagnoses with different prognoses, in obese patients, they are associated with the presence of sleep-disordered breathing. It is obstructive sleep apnea that seems to be a key factor contributing to the clinical picture of the so-called obese patient with COPD, and early diagnosis and treatment can reverse the negative impact of the disease on patients' health.

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