Morbid obesity, defined as a body mass index (BMI) greater than 40 kg/m², has implications for patient morbidity and mortality, hospital length of stay, resource allocation, and cost. Over time, physiologic changes related to morbid obesity occur in all body systems, and are particularly evident in the pulmonary system. Loss of functional residual capacity (FRC), restrictive and obstructive airway patterns, and alterations in gas exchange predispose the morbidly obese patient to conditions such as obstructive sleep apnea (OSA) and obesity hypoventilation syndrome (OHS). These conditions contribute to a marked decrease in pulmonary reserve, and when systemic insults such as traumatic injury or illness occur, respiratory failure may develop. Pulmonary anatomy and physiology, including lung capacities, compliance, resistance, and morphological changes that occur over time in the morbidly obese patient, will be discussed. Airway management and mechanical ventilation strategies used in the treatment of acute respiratory failure in the patient with morbid obesity will be reviewed based on current literature and evidence-based guidelines. The role of the nurse as part of the multidisciplinary team in assessing and implementing effective treatment strategies for the morbidly obese patient through the continuum of pulmonary dysfunction will be introduced.
decrease their quality of life and may place them at risk for sudden death related to stroke and cardiac events. These co-morbidities include pulmonary and cardiovascular disease, hyperlipidemia, degenerative joint disease, cancer, infertility, and diabetes. In her book, Kaufman, a medical expert on juvenile diabetes, coins the phrase “diabesity” and explores the causal relationship between the obesity epidemic and the increase in juvenile diabetes and type 2 diabetes mellitus. While a causal relationship between all comorbidities and obesity has not been established, morbidly obese patients with significant weight loss decreased the severity of their comorbidities, suggesting obesity does have an effect on the development of these preexisting conditions. Preexisting conditions increase the risk of complications in patients with morbid obesity when they experience critical illness or injury. Complications specific to the pulmonary system have significant physiologic consequences that would suggest an increased risk of critical illness.

### Anatomy and Physiology

The physiologic changes that accompany morbid obesity affect all body systems; here the emphasis is on the pulmonary system, with respiratory failure being one of the most frequent complications. Using spirometric models as a reference, changes in pulmonary function with morbid obesity can be visualized. Increased thoracic and abdominal mass alters lung volumes, resulting in a decreased functional residual capacity (FRC), expiratory reserve volume (ERV), and total lung capacity (TLC; see Fig. 1). Adipose deposits in the muscles of the abdomen, diaphragm, and intercostals impede chest wall expansion and diaphragmatic excursion.

### Table 1. Body Mass Index

<table>
<thead>
<tr>
<th>BMI</th>
<th>Underweight</th>
<th>Thin</th>
<th>Ideal</th>
<th>Overweight</th>
<th>Obese</th>
<th>Severely obese</th>
<th>Morbidly obese</th>
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<tbody>
<tr>
<td>&lt;16 kg/m²</td>
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<td>16–18 kg/m²</td>
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<td>19–25 kg/m²</td>
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<td>26–29 kg/m²</td>
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<tr>
<td>30–34 kg/m²</td>
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<td>35–39 kg/m²</td>
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<td>40–49 kg/m²</td>
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</table>

FIG. 1. (a) Normal lung volumes and (b) morbidly obese lung volumes.
decreasing lung compliance, defined as the ability of the lung to be inflated, especially in the supine position. Alterations in FRC may be significant enough to cause small airway closure, ventilation perfusion mismatch, right to left shunting, and arterial hypoxemia. Decreasing FRC is seen exponentially with increasing BMI. Therefore, it must be concluded that obesity has a negative impact on lung function even before a patient is hospitalized.8,9

It is estimated that approximately 30% of patients with morbid obesity have obesity hypoventilation syndrome (OHS) also known as Pickwickian syndrome. This syndrome, not to be confused with obstructive sleep apnea (OSA), is thought to be caused by inadequate diaphragmatic and lung expansion, resulting in insufficient gas exchange. Although OHS can exist independently, it is frequently associated with OSA, which is characterized by recurrent upper airway obstruction resulting in apnea, oxygen desaturation, and awakening from sleep. Over time, OHS leads to hypoxemia, hypercarbia, and chronic respiratory acidosis. Since OHS is commonly underdiagnosed in routine health exams, a significant proportion of patients present at hospitals already in acute respiratory failure (ARF).10,11 For these reasons, morbidly obese patients have little pulmonary reserve and decompensate rapidly with illness or injury.

**Noninvasive Positive Pressure Ventilation**

When significant respiratory distress is evident, initiation of noninvasive positive pressure ventilation (NPPV) should be considered. Application of positive pressure via mask or artificial airway opens collapsed alveoli, increases FRC, reduces work of breathing, and improves gas exchange.12 With NPPV, this is accomplished without the potential complications associated with invasive airways, such as aspiration pneumonia, vocal cord injury, and increased need for sedation.13 The use of NPPV may also offer direct mechanical benefits to the heart, as afterload is reduced and cardiac output is enhanced.14 Patients experiencing moderate to severe respiratory distress, including tachypnea, accessory muscle use, abdominal breathing, shortness of breath, PCO2 greater than 45 mm Hg, and pH less than 7.35, may benefit from a trial of NPPV.12,13

Early initiation of NPPV is advised, as the consequent response to therapy can be assessed and more invasive therapies initiated if required. Contraindications for NPPV include medical instability, fluctuating level of consciousness, inability to protect the airway, excessive secretions, noncooperation or agitation, inability to fit mask, recent upper airway or gastrointestinal surgery, and profound hypoxemia, shock, or acidemia.12–14 The use of NPPV may also be beneficial in averting respiratory failure in patients with morbid obesity when applied during the first 48 hours postextubation, specifically when presenting with hypercapnic respiratory failure.15

**Definitive Airway Management**

If NPPV is not possible or is unsuccessful, the patient should immediately undergo tracheal intubation to secure a definitive airway.16 Careful patient assessment for risk factors such as short neck, facial edema, and swollen tongue should be performed, since they can be predictors of difficult airway placement. The modified Mallampati (MMP) classification is used to evaluate the patient’s airway. However, research supports the use of the extended Mallampati score (EMS) in the patient with morbid obesity. The EMS is a Mallampati assessment with craniocervical extension allowing for greater mouth opening, and superior predictive values in the evaluation of the morbidly obese patient’s airway17 (see Fig. 2). Patients with acute or chronic cervical spine issues are assessed using the MMP, which maintains the head in a neutral position.

In addition, careful consideration should be given to the skill level of the clinician performing the intubation, and the equipment available required for a safe intubation. Required intubation equipment should be readily available on a[

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**Table 2. Difficult Airway Cart**

<table>
<thead>
<tr>
<th>Topical anesthesia agents:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidocaine (4%) viscous lidocaine (2%)</td>
</tr>
<tr>
<td>Topical vasoconstrictor: oxymetazoline (0.05%)</td>
</tr>
<tr>
<td>Small equipment: mucosal atomizer device with syringes</td>
</tr>
<tr>
<td>Magill forceps</td>
</tr>
<tr>
<td>Cricothyrotomy kit, wire cutters, bite blocks</td>
</tr>
<tr>
<td>Trachlight: assembled</td>
</tr>
<tr>
<td>Tracheostomy tubes, 6.0–8.0</td>
</tr>
<tr>
<td>Disposable LMAs sizes 3, 4, 5 with stabilization bars</td>
</tr>
<tr>
<td>Combitube</td>
</tr>
<tr>
<td>Nasal intubation equipment</td>
</tr>
<tr>
<td>Cricothyrotomy kit (percutaneous)</td>
</tr>
<tr>
<td>Jet insufflators</td>
</tr>
<tr>
<td>Glidescope</td>
</tr>
</tbody>
</table>

LMAs, laryngeal mask airways.
difficult airway cart (see Table 2). Obese patients may also have undiagnosed obstructive sleep apnea, which can obstruct their airway while they are in the supine position. Elevation of the head and shoulders to a 25° “head up” or ramped position, prolonged pre-oxygenation, and the use of an adjustable angle laryngoscope may mitigate difficulties with airway placement. The ramped position may be achieved by placing blankets or pillows under the head and upper torso of the patient to align the external auditory meatus and the sternal notch horizontally17,18 (see Fig. 3). If direct visualization of landmarks is not possible, video-laryngoscopic guided intubation has been shown to be successful in the morbidly obese patient with a difficult airway. An intubating laryngeal mask airway (LMA) or esophageal-tracheal double lumen airway (Combitube9) may be alternatives to an endotracheal tube and are especially suited as rescue devices if ventilation or intubation becomes difficult.17

**Tracheostomy**

Morbid obesity is associated with increased frequency of life-threatening complications from conventional tracheostomy. Special operative techniques and tracheal device considerations are necessary for tracheostomy placement. Attention must also be given to maintaining the airway and preventing inadvertent loss of the airway.17,18 Due to increased neck tissue thickness caused by adipose deposits, standard tracheotomy tubes may be too short and curved (skin to trachea depth length) for use in the patient with morbid obesity. This leads some clinicians to use modified longer tubes (see Fig. 4). However, postoperative management of modified tubes may be complicated by related risks of occlusion or dislodgement. Furthermore, patients with morbid obesity may have a greater chance of bleeding, scarring, and infection at the tracheal insertion site. Despite technical problems, such as difficulty locating landmarks on short obese necks, percutaneous tracheostomies can be performed, and although higher procedural complication rates have been reported, there is at this time no consensus as to the degree of risk when performed by experienced clinicians.18,19

Nursing and respiratory care of the morbidly obese patient with a tracheostomy includes thorough assessment and care of the tracheal insertion site, secretion management, and confirmation that the tracheal tube remains securely in place. Use of an appropriate tracheotomy tie/holder, such as a wide-padded tracheostomy tape, provides secure tube position and patient comfort. Extension pieces for easier tracheostomy access and cuff pressure monitoring should be utilized when assessing and caring for the morbidly obese patient with a tracheostomy. An extra tracheotomy tube at the patient’s bed side is paramount for safe patient care in case the tracheotomy tube becomes dislodged. Dedicating one clinician to securing the tracheotomy (or endotracheal tube) when transferring or changing the patient’s position should also be considered standard practice, especially if the patient is receiving mechanical ventilation, as even a transient loss in positive pressure may result in rapid derecruitment and hypoxia.8,17,18

**Mechanical Ventilation**

Mechanical ventilation for the morbidly obese patient with respiratory failure is challenging. Several studies have advocated use of different ventilatory strategies for the morbidly obese. However, the majority of these modes were employed in healthy obese patients undergoing bariatric surgery.15 Therefore, it is necessary to recognize that these strategies may not be effective in patients with lung diseases. As noted, morbidly obese patients present with decreased FRC, which may lead to alveolar collapse and atelectasis, particularly in dependent lung areas. In addition, total compliance of the respiratory system is reduced due to intrapulmonary (lung) and extra pulmonary (chest and abdominal) forces. This is especially true in the supine position. Higher than normal airway pressure may be required to create distending pressure across the lung, also known as transpulmonary pressure (airway pressure minus pleural pressure; see Fig. 5). Once airway opening has been achieved, higher positive end expiratory pressures (PEEP) and plateau pressures may be required to prevent distal airway closures and to allow for effective ventilation and oxygenation.20 In one study, a PEEP of 10 cm H2O improved oxygenation and lung mechanics in morbidly obese patients undergoing abdominal surgery, although, it did not demonstrate the same benefit in normal weight patients.21

In ventilating morbidly obese patients, as with normal weight patients, a lung protective approach is necessary. This approach includes: low tidal volumes ($V_t$), particularly in patients with acute lung injury (ALI) or the acute respiratory distress syndrome (ARDS), is supported in the literature. The protocol used in the ARDS Network recommends the use of a low $V_t$ (6 mL/kg predicted body weight) and the maintenance of a plateau pressure less than 30 cm H2O. These ventilator strategies were associated with an 8.8% absolute risk reduction in hospital mortality compared with conventional ventilation ($V_t = 12$ mL/kg predicted body weight).22 Further review of ARDS Network patients revealed that 58.6% of the studied population were overweight or had higher grades of obesity and the important primary and secondary outcomes were not significantly different between obese, overweight, and normal weight patients.23 The data suggest that obese patients with acute respiratory failure may be ventilated, as suggested by the ARDS Network Study protocol. It is
important to note that $V_t$ is calculated based on ideal or predicted body weight and not actual body weight, since the size of the lung does not change significantly with increased body weight.22,23 Another consideration with mechanical ventilation in patients with morbid obesity is that pleural pressures are typically elevated secondary to decreased intra and extra pulmonary compliance. As mentioned, obese patients may require higher then recommended ventilating pressures, and an absolute goal of maintaining plateau pressures under 30 cm H$_2$O may not always be possible.20,24

Airway pressure release ventilation (APRV) is a mode of mechanical ventilation that may also provide lung protection. This mode of ventilation, also known as continuous positive airway pressure (CPAP) with release, is a timed elevated baseline pressure that facilitates lung recruitment and oxygenation with short timed releases to assist in carbon dioxide removal. Advantages of APRV include the ability of the patient to breathe spontaneously and require less sedation while having minimal adverse effects on cardiac function.24 APRV is an accepted mode of ventilation for patients with ALI/ARDS and is beneficial for those patients unable to maintain adequate arterial oxygenation and ventilation using low tidal volume strategies.23,25 The use of APRV may be an ideal mode of ventilation in the morbidly obese patient with restrictive lung disease, as pressure over a prolonged period of time facilitates recruitment of all lung regions while minimizing

<table>
<thead>
<tr>
<th>I.D. Size (mm)</th>
<th>Length (mm)</th>
<th>I.D. Size (mm)</th>
<th>Length (mm)</th>
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<tbody>
<tr>
<td>6.0</td>
<td>110.0</td>
<td>8.0</td>
<td>76</td>
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<tr>
<td>7.0</td>
<td>120.0</td>
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<td>8.0</td>
<td>130.0</td>
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<td>9.0</td>
<td>140.0</td>
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**FIG. 4.** Comparison of standard and extra length tracheostomy tubes.

**FIG. 5.** Transpulmonary pressures.
Sedation and Mechanical Ventilation

Sedative–hypnotics and benzodiazepines are commonly used with mechanical ventilation to improve patient comfort and synchrony with the ventilator, decrease patient recall, and improve tolerance to medical and nursing care. An essential part of the nursing assessment is to achieve a therapeutic outcome while avoiding oversedation. Obesity affects distribution, binding, and elimination of medications, and appropriate weight adjustments should be made for lipophilic drugs.8,28,29 Propofol, a sedative–hypnotic agent commonly used in conjunction with mechanical ventilation, is highly lipophilic and, with prolonged infusion, accumulates in tissue and fat. Once discontinued, it is reabsorbed into the plasma, resulting in potential delayed awakening and liberation from mechanical ventilation. Possible complications associated with mechanical ventilation, including damage to airway structures and ventilator associated pneumonia, are well documented in the literature.29,30 Those strategies that can be used to minimize ventilator days will impact favorably on patient outcome and hospital costs. Burns et al. reported that the use of algorithms targeting sedation end points and protocols to wean patients off sedatives resulted in a significantly shorter duration of mechanical ventilation as well as shorter Intensive Care Unit (ICU) and hospital stays.28

Efforts to decrease anxiety should not be limited to the use of pharmacologic interventions. All attempts should be made to utilize a holistic approach when dealing with the anxious mechanically ventilated patient. Interventions may include decreasing auditory and visual stimuli, complementary and alternative medicine (e.g., music therapy, Reiki, therapeutic touch), uninterrupted sleep, and therapeutic patient communication.31,32

Positioning and Mobilization

Positioning of patients with obesity during ventilation has an impact on lung mechanics and oxygenation. Several studies suggest the ideal position for mechanically ventilated obese patients is reverse Trendelenburg at 45°. This position results in increased tidal volumes, reduced respiratory rate, and improved oxygenation compared with the supine and head of bed to 90° positions.33 Mobilization of the patient with morbid obesity receiving mechanical ventilation is generating renewed interest. In a randomized controlled study, critically ill patients receiving mechanical ventilation who were mobilized had fewer days with delirium, fewer ventilator days, and better functional status at hospital discharge compared to the group of patients not being mobilized.34 Mobilization of patients with obesity requires experienced nursing and physical therapy staff in order to ensure that transfers and weight-bearing exercises occur safely. In general, the nursing staff caring for morbidly obese patients with pulmonary dysfunction can face challenges. Simple tasks such as turning the patient and providing hygiene may cause injury to staff members and the patient if not performed with adequate personnel, specialized equipment, and training. In fact, Drake et al. report that caring for patients with morbid obesity requires 100% more time and staff to complete the same necessary tasks as with a nonobese patient.35

Psychosocial

With all patients, it is important to realize the psychosocial challenges they face. As suggested in one study, morbidly obese patients may feel isolated and depressed by their situation, or they may have problems with their family and interpersonal relationships.35,36 As caregivers, it is crucial to be awake of preexisting stressors and/or biases in an effort to provide the most holistic care possible. Once liberated from mechanical ventilation and when stable enough to begin physical therapy in preparation for discharge, it must be determined what respiratory aids the patient will require for home care. At this point, knowledge of family and personal problems is integral for continuing care of the patient.36 According to Pokorny et al., the need to ascertain a “better understanding of how these patients manage their home care and burdens placed on the family assisting in care would help nurses and other healthcare professionals improve their care.”37

Summary

Pulmonary management of the patient with morbid obesity presents a challenge for all clinicians involved in their care. Patients with morbid obesity often present with mechanical and morphological changes that negatively impact airway management, oxygenation, and ventilation. The morbidly obese patient has little pulmonary reserve when acutely injured or ill, and severe respiratory decompensation can rapidly transpire. Early recognition and definitive management can help improve outcomes in this subset of hospitalized patients. Much of the current data about the pulmonary management of patients with morbid obesity come from bariatric surgery experiences. Additional research about optimal strategies for treating respiratory compromise, especially mechanical ventilation in the acutely ill morbidly obese patient, is needed, as this patient population has historically been excluded from most randomized clinical studies.

Disclosure Statement

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References


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