

Perspectives

Recovery Strategies from the OR to Home

ABSTRACT

The word obesity has its origins in the Latin language; it refers to the state of becoming "fattened by eating." Obesity is a relatively common health condition, and its prevalence is increasing nationally and globally. Of all Americans between the ages of 26 and 75, 10 - 40% are obese, and nearly 5% are morbidly obese. The health consequences of obesity range from chronic conditions that reduce the general quality of life to a significantly increased risk of premature death. Along with other organs, the respiratory system is compromised by obesity. In their article, Gentile and Davies, discuss the many challenges to health professionals when caring for the respiratory needs of the obese, and how to reduce complications associated with their hospitalization. Critically ill morbidly obese patients are more likely to be intubated and remain intubated. They will stay in the ICU longer and are at risk for mortality during their stay when compared with their non-obese counterparts. In his article, Dr. Op't Holt discusses the role of tracheostomy in the mechanically ventiated obese patient.

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Respiratory Care of the Morbidly Obese Patient

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Approximately two thirds of US adults are overweight or obese.¹ Overweight may be defined as a body mass index (BMI) 25–29.9 kg/m², obesity >30 kg/m² and morbid obesity refers to those with a BMI >40 kg/m². BMI is not an ideal measure of body weight distribution because it includes muscle, but it is a universally accepted measurement, useful and simple to apply. The prevalence of obesity is increasing at an alarming rate worldwide. Many public health experts consider obesity an epidemic, with a 10% increase in prevalence as compared with the previous decade. Also alarming is that childhood obesity rates have nearly tripled since 1980, from 6.5% to 16.3%.²

The health consequences of obesity range from chronic conditions that reduce the general quality of life to a significantly increased risk of premature death. Morbid obesity is associated with a greater incidence of medical and surgical pathology. Many diseases such as diabetes mellitus, hypertension, hyperlipidemia, cardiovascular disease, stroke, infertility, degenerative joint disease, gallstones and some types of cancers are associated with obesity. Midlife overweight and obesity are strongly associated with increased risk of death.³ More than 400,000 people in the US die each year as the result issues related to obesity.⁴ Additionally, the obesity epidemic is taking a toll on the U.S. economy by adding billions of additional dollars in health care costs. Currently, 42 states have specific plans with strategies and goals to lower the occur-

rence of overweight, obesity and obesity-related chronic diseases.

Obese patients may enter the health care system from a variety of access points. The specific needs of obese patients must be addressed whether the hospital admission is for surgery to treat their obesity via bariatric surgery, unrelated surgery, or a nonsurgical disorder. Patients should be assessed using a multidisciplinary, systematic approach including access to diagnostic imaging, laboratories, and specialist services such as orthopedics, psychology, nutrition, endocrinology, cardiology, and pulmonary medicine. All clinicians should be knowledgeable in the physiology and management of obese patients as well as the equipment and protocols of their respective institutions. Safe and successful treatment of the obese patient necessitates an established level of organizational commitment, including staff education, clinical expertise, and specific care protocols.

Obesity and the Respiratory System

Along with other organs, the respiratory system is compromised by obesity. Adipose tissue impairs respiratory function in both adults and children. Obesity may affect respiratory function in a number of ways. Carbon dioxide production increases as a function of body weight. Obese subjects consume approximately 25% more oxygen than nonobese subjects at rest.⁵ Severely obese patients are often hypoxemic, especially in the supine position.⁶ Ventila-

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Continued on page 4

Tracheotomy in the Obese Patient

Tim Op't Holt, EdD, RRT, AE-C, FAARC

Obesity is defined by the National Institutes of Health (NIH) as a body mass index (BMI) of > 40 or > 35 with life-threatening comorbidities.¹ According to the Centers for Disease Control and Prevention (CDC), the prevalence of obesity (BMI ≥ 30) continues to be a health concern for adults, children and adolescents in the United States. Data from the most recent NHANES survey shows that among adult men, the prevalence of obesity was 31.1% in 2003—2004, and 33.3% in 2005—2006, a small and not significant change.² Among adult women, the prevalence of obesity in 2003—2004 was 33.2%, and in 2005—2006 was 35.3%, again a small and not significant change. Obesity represents a significant challenge to the healthcare system, particularly when the patient requires mechanical ventilation.

Indications for tracheotomy in the obese

Obese patients are at a higher risk for medical complications, compared with their non-obese counterparts. Obesity has been shown to be an independent risk factor for death in the intensive care unit (ICU). The obese often require lengthy hospitalizations due to their comorbidities and complications, so the need for mechanical ventilation is not uncommon. Critically ill morbidly obese patients are more likely to be intubated and remain intubated. They will stay in the ICU longer and are at risk for mortality during their stay when compared with their non-obese counterparts.³ As with non-obese patients, the obese require tracheotomy for the maintenance of an airway and to provide for mechanical ventilation, but some morbidly obese patients require tracheotomy to facilitate ventilation in obesity hypoventilation syndrome (OHS) and obstructive sleep apnea (OSA). Obesity is a relative contraindication to percutaneous dilational tracheostomy (PDT) because of the assumption that identification of neck anatomy will be difficult.⁴

Hazards, complications and mortality due to tracheotomy in the obese

In one study, a tracheostomy was performed in 89 morbidly obese patients out of 427 critically ill patients. A total of

The obese often require lengthy hospitalizations due to their comorbidities and complications, so the need for mechanical ventilation is not uncommon.

27 complications were recorded in 22 morbidly obese patients (25%) compared to 65 complications in 49 patients (14%) of the control group.⁵ The most common serious complication was tracheostomy tube obstruction. In the study by Heyrosa of 142 obese patients (BMI > 35) undergoing PDT, 4 procedures were started percutaneously, but had to be converted to open tracheostomy procedures, due to bleeding, inability to pass the guidewire and loss of airway control.⁴ The frequency of adverse events was not significantly different compared to tracheostomy in the non-obese. PDT was complicated by the inability to identify anatomic landmarks, non life-threatening hemorrhage, and malposition of the tracheostomy tube, resulting in hypoxemia and bradycardia. Since the incidence of complications during PDT in the obese was no different from that in the non-obese, the authors concluded that elective PDT was a safe procedure in the obese. They attributed their success to familiarity with the procedure (Ciaglia), proper sizing of the tracheostomy tube, and availability of extra-long tubes when needed. El Solh and Jaafar found an increase in the number of complications due to tracheotomy in the obese.⁵ Complications included minor bleeding, cuff leak, a non-fatal tube occlusion by a

blood clot (in spite of high humidity), accidental decannulation followed by extra-tracheal tube placement, and subcutaneous emphysema (resulting in bilateral tension pneumothorax and cardiorespiratory arrest). I observed this on one morbidly obese patient, where the ventilator high pressure alarm sounded and it was quickly realized that the patient's tracheostomy tube has slipped into the pretracheal space. This resulted in immediate subcutaneous emphysema and subsequent cardiac arrest, from which the patient did not recover. Obstruction within the first 24 hours after surgery is usually the result of tube impingement on the posterior wall of the trachea, partial displacement into the mediastinum, blood clot, or mucus plug. In El Solh and Jaafar's study of 89 obese patients with tracheostomy, the incidence of complications due to tracheostomy was 25%, with an estimated mortality of 2%.⁵

In a retrospective chart review, Darrat and Yaremchuk reported a non-statistically significant increase in mortality in obese patients after tracheotomy, but they concluded that this increase was clinically significant.⁶ They reported that a morbidly obese individual was 83% more likely to die within 30 days after tracheotomy than an individual who is not morbidly obese.

Unrelated to the surgical procedure, the narrow cloth ties used to secure the tracheostomy tube can burrow into the folds of the neck, which may damage the skin. The use of wider or thicker ties may help prevent this. Another complication is skin candidiasis that occurs in warm, moist skin folds, such as the neck of an obese person with a tracheostomy. Comorbidities contributing to the growth of *Candida* spp. are immunosuppression, diabetes mellitus, infection, chronic steroid use, and hyperhidrosis. Candidiasis is characterized by scaling erythema and perhaps small pustules. The patient may complain of itching or burning.⁷

Preventing complications from tracheotomy in the obese

Since tracheotomy is often inevitable in obese patients, prevention of complications is important. El Solh and Jaffar⁵ noted that they do the following in varied circumstances to avoid complications:

- Monitor morbidly obese patients in the ICU for at least 72 hours, even when mechanical ventilation has been discontinued;
- Apply an elastic bandage to keep the chin away from the stoma;
- Use an extension tube between the ventilation circuit Y and the tracheostomy tube (This does, however increase mechanical dead space by not more than 50 mL and facilitates mechanical ventilation).



Figure 1. Shiley TracheoSoft® XLT Extended-Length Tracheostomy Tubes. Courtesy of Covidien-Nellcor, Boulder, Co.

- Insert a metal tracheostomy tube once the tracheostomy tract is well-formed (presumably after cessation of mechanical ventilation).

There are two surgical approaches to creating and maintaining the stoma. One is called “defatting” or cervical lipectomy, where the surgeon reconfigures the neck to accommodate the tracheostomy tube.⁸ With this procedure in patients whose BMI exceeded 55, there was a 43% (10 of 23 patients) incidence of complications including site infections, abscesses, hemorrhage necessitating neck exploration, and tracheal stenosis. Despite this incidence of complications, the authors concluded that defatting is safe and effective in morbidly obese patients. All patients in this study required surgical closure of the tract, so the surgeon should plan for a second procedure to do so. A further surgical procedure to maintain the tract is referred to as a Bjork flap.⁹ In this procedure, a stoma is constructed via an inferiorly based Bjork flap to form the inferior wall of the stoma, combined with a superiorly based skin flap to form the superior wall. As with the defatting proce-



Figure 2. Dale® Medical Tracheostomy Tube Holder with extension strap and moisture wicking lining for wider necks.

dure, this needs to be surgically closed after decannulation.

Splitting a conventional endotracheal tube and the use of a long tracheostomy tube are 2 other methods to facilitate tracheostomy in the obese. The split endotracheal tube method involves fashioning a tracheostomy tube out of a standard endotracheal tube. The stoma is intubated with an endotracheal tube and the 15 mm adapter is removed. The endotracheal tube is cut with scissors lengthwise to the opening of the stoma, and the adapter reinserted. The tube may then be sutured to the skin. A neater process is to use a special long tracheostomy tube that has a long proximal extension to allow for the longer distance from the anterior tracheal wall to the opening of the stoma at the skin.¹⁰ (Figure 1)

Standard practice for the therapy of topical candidiasis involves keeping the skin clean and dry using a gentle soap or no-rinse skin cleanser and applying an antifungal powder, cream, or ointment locally. If these agents fail to resolve the antifungal infection, oral antifungal medications will be needed. Fluconazole may be effective as it is highly water-soluble, transported to the skin in perspiration, and concentrated by evaporation. For severe cases, Burrow’s solution (water and aluminum acetate) soaks several times a day may help promote dryness. Using a 1% acetic acid solution as a compress several times a day also has been suggested.¹¹

Tracheostomy tube securement is provided by the use of cotton twill tape or with a commercial device. Twill tape is a flat woven cotton cord, provided in a roll. To apply twill tape, two pieces totaling longer than the circumference of the patient’s neck are cut from the roll. A slit is cut in one end of each piece of tape and the tape is threaded through the hole in the tracheostomy tube phlange and slit. The two pieces of tape are placed around the patient’s neck in opposite directions and tied in a bow on the side of the neck. The ties should be just tight enough to allow the passage of one or two fingers between the tie and the neck. Commercial devices are usually made of a length-adjustable flat plastic/foam tape and have hook and loop (e.g. Velcro®) fasteners on each end, which are threaded through the holes in the phlange of the tracheostomy tube. While twill tape is inexpensive, a commercial device may be easier to prepare and take less time to apply. Twill tape rolls into a band about the neck that may irritate the neck. The commercial device remains flat. Much of the decision about which securement to use is guided by hospital preference and cost. In the obese patient, the flat commercial device with a moisture wicking lining might be more ad-

vantageous because it remains flat and does not absorb bodily fluid (Figure 2). Used correctly, neither securement should slip or allow decannulation.

In summary, the presence of obesity is not a contraindication to tracheostomy, either the open or percutaneous technique. Tracheostomy is likely to be needed for patients with respiratory failure, obstructive sleep apnea, or obesity hypoventilation syndrome. Obesity increases the likelihood of medical complications during hospitalization. The hazards of tracheostomy in this cohort have been identified as have the procedures by which they may be avoided. The stoma and access to the tracheostomy tube must be maintained. The peristomal skin surface must be kept clean and dry to avoid candidiasis.

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Respiratory Care of the Morbidly Obese Patient – Continued

tion/perfusion mismatch is more obvious in obese patients. The lung bases have sufficient perfusion, but are hypoventilated due to airway closure and alveolar collapse from the added weight of the chest wall.^{7,8} It is generally accepted that the compliance of the respiratory system is low in obesity, mainly because of the effect of obesity on the chest wall.^{9,10,11} The compliance of the total respiratory system and of the lung decreases exponentially as BMI increases, whereas the compliance of the chest wall is only minimally affected by BMI.¹² Subjects with obesity also exhibit increased airway and respiratory system resistance.

There is a clear association between dyspnea and obesity. Obesity increases the work of breathing because of the reductions in both chest wall compliance and respiratory muscle strength.¹³ This creates an imbalance between the demand on the respiratory muscles and their capacity to generate tension, which leads to the perception of increased breathing effort. Furthermore, dyspnea in obese patients could mask other associated conditions, such as respiratory and heart diseases. Increasing BMI is typically associated with a reduction in forced expiratory volume in one second (FEV1), forced vital capacity (FVC), total lung capacity (TLC), functional residual capacity (FRC) and expiratory reserve volume (ERV). The increased lung and respiratory system resistance in obesity is due to the reduction of lung volume.^{14,15,16} Lung volumes, especially FRC and ERV, decrease as body weight increases. Clinicians can estimate an approximate 0.5% decrease in VC, TLC, and RV with each unit increase in BMI. The diffusing capacity of the lung for carbon monoxide (DLCO) increases approximately 0.3% for each unit increase in BMI. With FRC and ERV, the changes are more dramatic.

Obese patients have a reduced functional residual capacity. This will lead to airway closure and oxygen desaturation in the supine position, as well as more rapid desaturation if difficulty is encountered intubating the trachea. A careful history should be taken of exercise tolerance and obstructive sleep apnea. Sleep apnea and the obesity hypoventilation syndrome are common as BMI increases. Pulse oximetry may be a useful screening tool for further evaluation of a complete sleep study. Consideration should be given to the use of continuous positive airway pressure (CPAP) or noninvasive positive pressure ventilation (NPPV) for those affected.

Hypercapnic respiratory failure and cor pulmonale are frequently associated with obesity. The combination of obesity (BMI >30 kg/m²) and hypercapnia (PaCO₂

> 45 mm Hg) while awake and without any other known causes of hypoventilation defines the Obesity Hypoventilation Syndrome (OHS).¹⁷ Common symptoms of OHS are respiratory failure, severe hypoxemia, hypercapnia and pulmonary hypertension. Most patients with obesity hypoventilation syndrome also have OSA, while others have obesity hypoventilation syndrome but not obstructive sleep apnea suggesting that obesity alone can lead to chronic hypoventilation. In severely obese (BMI >35 kg/m²) hospitalized patients, up to 31% have hypercapnia with no other obvious etiology, with the prevalence of OHS increasing with increasing BMI.¹⁸

During auscultation of the chest, wheezing in obese patients may be due to airway closure rather than asthma. The differential diagnosis may be confirmed by pulmonary function testing and response bronchodilator therapy. Obesity is associated with numerous measures of asthma severity and management, including degree of symptoms, days of missed work, medication utilization and medical compliance. Patients with obesity frequently report dyspnea and wheezing and are therefore often given therapy for asthma without objective diagnostic confirmation by pulmonary function testing.¹⁹ An accurate diagnosis is important because dyspnea related to other mechanisms or diseases may require a different therapeutic strategy. Thus, the diagnosis of asthma or chronic obstructive pulmonary disease (COPD) should not be based solely on symptoms but should include spirometric confirmation.

Thoracic restriction associated with obesity is simply due to the mechanical effects of increased weight on the diaphragm and the chest wall. This leads to impedance of the diaphragm excursion and reduced thoracic compliance. A restrictive pattern (total lung capacity < 85% predicted) is usually seen only in severe obesity, when the patient's weight-to-height ratio is 0.9–1.0 kg/cm or greater.²⁰ However, a restrictive disorder may still be attributed to obesity when the weight-to-height ratio is less than 0.9 kg/cm. This typically occurs in the presence of central fat deposition, which is indicated by a waist-to-hip ratio of 0.95 or greater.²¹ It is still sensible to investigate other causes of restrictive impairment, such as interstitial lung disease or neuromuscular disease.

A low FEV1/FVC ratio (<70%), as indicated by pulmonary function testing is indicative of airflow obstruction, is typically not associated with obesity.²¹ Respiratory muscle strength could also be decreased in obesity, as signaled by reduced maximal inspiratory pressure in obese subjects compared with those normal body weight. Diffusion capacity may also be increased in obesity.²² Respiratory muscle weakness in obesity has been associated with muscle

inefficiency, a result of reduced chest wall compliance and lung volumes.^{21,23}

The end result of the respiratory system compromise is significant exercise capacity limitation in obese patients. Surprisingly, cardiorespiratory fitness as defined by maximal oxygen consumption, is generally not normal in obese patients, functional status during exercise such as walking is reduced because of the higher metabolic cost of carrying the extra body weight.

Obese patients in the Intensive Care Unit

Patients who are obese and require admission to the intensive care unit (ICU) pose significant clinical care and safety issues. Specifically designed beds are required to accommodate the size and weight, and significant challenges exist in mobilizing or transporting such patients.

Many significant derangements in physiology must be accounted for when treating the obese patient. As a result of prolonged immobilization, the risks of deep-vein thrombosis or pulmonary embolism are increased in obese patients. Cardiovascular effects may include suppressed left ventricular contractility, low ejection fraction and ultimately, diminished cardiac output. GI disorders are also more common in this patient population with a combination of increased intraabdominal pressure, high volume capacity and low pH of gastric contents, leading to an increased risk of esophageal reflux and an elevated risk of aspiration pneumonia. Alterations in pulmonary function, with decreased VC, TLC, and FRC with increased airway resistance also have important implications in the treatment of obese patients requiring mechanical ventilation. Obesity affects the pharmacokinetics and pharmacodynamics of many drugs due to changes in tissue distribution, hemodynamics and blood flow to adipose, splanchnic and other tissues. Plasma composition and liver and kidney function are also altered. Obese patients with diabetes should have strict perioperative glycemic control. Obesity requires specific adjustment of drug regimens, elevated parameters of mechanical ventilation, consumes considerable personnel resources, and is associated with a high risk of ICU complications. Furthermore, obesity has been linked to increased morbidity and mortality resulting from acute and chronic medical problems. Obese patients incur different injuries after severe blunt trauma than their non-obese counterparts. Despite sustaining fewer head injuries, obese patients suffer more complications, require longer stays in the hospital, more days of mechanical ventilation, and obesity is independently associated with mortality. Numerous epidemiologic studies have pointed to the association between mortality and increasing BMI in all age groups and for all categories

of death. Further complicating this issue is assessment of severity of illness by general scoring system is insufficient in predicting hospital outcome. At the present time acuity scoring systems, do not include BMI as a parameter used in calculations.

Airway Management Care of the obese Patients

Obesity significantly increases the complexity of airway management procedures. Difficulties with endotracheal intubation and airway management are more common in obese individuals. Patients with obesity are high risk for aspiration due to elevated intraabdominal pressure, gastric volume and low pH of gastric contents. A large neck with limited mobility, decreased mouth opening, large tongue, and short sternomental distance can pose serious challenges during endotracheal intubation attempts. Any factor that contributes to difficult laryngoscopy and subsequent viewing of the airway will increase the possibility of complications. Intubation may also be more difficult because of the presence of excess tissue at the back of the neck, or because of deposition of fat into the soft tissues of the neck. Larger doses of medications used to facilitate intubation are often needed to combat a greater volume of distribution.

Positioning the obese patient for intubation also provides unique challenges when compared to those of lower body weight. Intubation typically is performed while the patient is in the supine position. However, obese patients with decreased functional residual capacity accompanied by increased airways resistance leads to rapid and significant hypoxia in the supine position. Bag masking ventilation is difficult and requires high airway pressures due to the impaired pulmonary function created by weight on the chest wall. Various techniques including CPAP and high flow supplemental oxygen may be employed to avoid desaturation during intubation attempts.

Equipment selection must be carefully considered prior to airway management procedures in obese patients. Other than routine laryngoscope blades and endotracheal tubes, equipment should include laryngeal mask airways, flexible bronchoscopes, and an emergency cricoidotomy kit. Additional, planning must take place for the potential strength required to open, maintain, and properly place a secure airway in an extremely obese patient.

If a tracheostomy is required, secretions must be controlled to prevent the threat to the patient's airway. The trachea is usually close to the skin surface and easily accessible. For those patients with a thick short neck and excessive parapharyngeal fat deposits, it becomes more difficult for the surgeon to perform the tracheotomy

Tracheostomy ties should be longer and wider to prevent trauma within skin folds.

as the trachea may be buried deep in the tissue. A resultant wound must be managed like any other open wound. A non-adhesive, absorbent, 1-inch foam dressing will absorb excess wound drainage, protect the wound, and prevent injury from adhesives. Tracheostomy ties should be longer and wider to prevent trauma within skin folds. A specially designed tube holder (Dale Medical Products) incorporates stretch material to accommodate any edema around the neck. An extension piece ensures a proper fit for obese patients. A moisture wicking lining on the skin side of the holder can help prevent pressure ulcers from occurring under the trach tie.

Mechanical Ventilation of the Obese Patient

Obese patients requiring admission to the ICU represent a considerable clinical challenge for all clinicians. Mechanical ventilation of the obese patients provides especially difficult due to significantly altered lung volumes and chest wall mechanics.

While obesity has been connected to decreased overall health and increased mortality, little is known about its effect on patients with acute lung injury (ALI) and acute respiratory distress syndrome (ARDS). Current mechanical ventilator practice to treat patients with ALI and ARDS supports the use of low tidal volume ventilation with adequate PEEP and an airway plateau pressure (Pplat) limit of 30 cmH₂O. A lung protective strategy designed to minimize alveolar overdistention has been shown to decrease mortality by 22% compared with a control ventilator strategy. However, this applied Pplat limit of 30 cmH₂O may be inadequate in morbidly obese patients because of the very reduced compliance of the chest wall and altered lung volumes. This issue has not been well studied in morbidly obese patients with ALI/ARDS because high BMIs are almost always an exclusion criteria for clinical trials that investigate lung protective strategies. When total respiratory compliance is considered in obese patients, the effects of

obesity on the chest wall must be separated from the effects attributable to decreased lung compliance, a hallmark symptom of ALI and ARDS. This characteristic has major implications for the successful and safe application of mechanical ventilation in obese patients.

When selecting mechanical ventilator settings for obese patients, there are important physiological factors are critical to consider. First, the pressure difference between airway opening and pleural space (transpulmonary pressure, Ptp) is the distending pressure across the lung. Pressures applied during mechanical ventilation reflect the sum of the lung and chest wall together. The Ptp is a critical measurement useful in determining risk of ventilator induced lung injury. Dramatic increases in airway pressure may be observed with minimal lung stretch and injury when the chest wall is restricted, reflected by raised pleural pressure. Obese patients can frequently be safely ventilated with relatively high applied pressures since transpulmonary pressures are quite low in this setting. Plural pressure can be measured by the use of an esophageal balloon placed into the patient. A challenge at the bedside is that pleural pressure is not routinely measured and therefore transpulmonary pressure is not known in most cases. Clinicians are often in a situation of having to estimate what pleural pressures are in any given patient.

In patients with ALI/ARDS, randomized-controlled trials have shown a mortality benefit with the use of 6 mL/kg tidal volume compared with 12 mL/kg.²⁴ One extremely important point is that 6 mL/kg must be calculated on the predicted body (PBW) weight rather than actual body weight (ABW). The PBW is based on height and gender. The rationale for using PBW versus ABW is that when a patient gains weight, the lung does not change in size. The calculated PBW can be found by using the formula: 50 + 2.3 (height in inches - 60). The formula for females: 45 + 2.3 (height in inches - 60). An illustrative example would be a male patient who is 72 inches tall but weight increases from 70 kg to 100 kg. This patient has a PBW of 77.6 kg and should receive a tidal volume 465 mL rather than 600 mL. The number of alveoli participating in gas exchange is difficult to predict at the bedside, there is no easy way to tell the proportion of lung participating in each tidal inspiration. Therefore, a volume targeted approach could lead to regional overdistention even when applied pressures are below the recommended 30 cmH₂O. Conversely, pressure targeted approaches could lead to marked increases in tidal volume, particularly in spontaneously breathing patients. Such patients can generate large transpulmonary pressures that may not be obvious to the clinician at the bedside. Whether us-

ing a volume or pressure based approach to mechanical ventilation, lung stretch should be evaluated and minimized in patients with ALI/ARDS to prevent worsening of lung injury. This is particularly important in obese patients who will require elevated mechanical ventilation settings.

Obesity in the ALI/ARDS patients often have obvious increases in pleural pressure and therefore plateau airway pressure of 30 cmH₂O may be exceeded. In addition, when PEEP requirements are high, only very small tidal volumes can be delivered if plateau pressures are kept below 30 cmH₂O.

Permissive hypercapnia (allowing carbon dioxide values to increase and pH to fall) is another strategy that can be employed for obese patient with ALI/ARDS. Obtaining any baseline arterial blood gas volume prior to intubation and mechanical ventilation is imperative to safely and effectively use this strategy. Many obese patients have elevated levels of arterial CO₂ at rest, thus attempting to correct it with mechanical ventilator setting may be futile.

PEEP in mechanically ventilated ALI/ARDS patient functions to increase lung volume and prevent recruited lung regions from collapsing. The level of PEEP that is required to achieve these effects, however, is influenced by several factors. One of the most important factors is the opening pressures of the small airways that subtend the alveoli. In ALI/ARDS, the opening pressure of small airways reflects the local disease severity and is increased by surfactant deficiency and accumulation of airway fluids. In morbidly obese patients, the opening pressure of small airways may increase further due to small airways dysfunction. In addition, as noted above, chest wall compliance is profoundly decreased in morbidly obese individuals. This will increase intrapleural pressure and decrease transpulmonary pressure at any given applied airway pressure. Thus, the level of PEEP needed to support equivalent oxygenation may be higher in morbidly obese patients than in patients with normal BMI. The fact that conventional levels of PEEP superimposed on high tidal volumes did not improve intraoperative arterial oxygenation of morbidly obese patient might support this concept. Ineffectiveness of PEEP in this setting, however, may also be secondary to redistribution of blood flow to non-ventilated regions resulting in increased intrapulmonary shunt in patients who have no lung disease. The effects of low and high levels of PEEP in obese patients with ALI/ARDS receiving lung protective low tidal volume ventilation may be more beneficial but it has not yet been studied. The number of lung units available is important. Collapse of alveolar units may occur due to surfactant dysfunction inherent to ALI/ARDS or from increased pleural pressures that in effect compress lung units leading collapse. These

Table 1. Classification of body mass index in adults	
Body mass index (kg/m ²)	Classification in adults
18.5	Underweight
18.5–24.9	Healthy
25–29.9	Overweight
30–34.9	Obesity class I
35–39.9	Obesity class II
>40	Obesity class III (morbid obesity)

alveoli can be recruited if the applied pressures are sufficient to overcome the opening pressure. Obese patients frequently develop considerable atelectasis, particularly in the posterior dependent lung zones due to the weight of the chest wall.¹⁷

The failure to fully account for the chest wall effects on airway pressures may lead to inappropriate therapy, such as inadequate titration of PEEP. Typically, PEEP values of 20–25 cmH₂O are required to maintain oxygenation in obese patients. Respiratory system mechanics have been studied in spontaneously breathing obese patients and in paralyzed and sedated post-operative obese patients. Obese patients have reduced forced residual capacity (FRC), lung compliance and increased chest wall impedance. FRC values in morbidly obese patients are often below closing volume, especially while in the supine position. This can result in closure of more lung units in the dependent lung zones during respiration worsening ventilation-perfusion mismatch and intrapulmonary shunt and thus hypoxemia. The gas exchange abnormalities likely are exaggerated in obese ALI/ARDS patients complicating ventilator management.

Morbid obesity is clearly associated with prolonged mechanical ventilation and an extended weaning period. The prolonged time of mechanical ventilation and a higher oxygen requirement reflect the numerous physiologic alterations in pulmonary function in the obese patient. Studies of conventional respiratory function tests have uniformly showed a reduction in functional residual capacity due to the effect of abdominal contents on the diaphragm. Liberation from mechanical ventilation is also delayed in morbidly obese patients due to increased work of breathing due to increased airway resistance, abnormal chest elasticity, and inefficiency of the respiratory muscles. The extra work in moving the chest is attributed to a decrease in chest wall compliance associated with the accumulation of fat in and around the ribs, the diaphragm, and the abdomen. It has been suggested that the reverse Trendelenburg position at 45° can facilitate the weaning process by allowing a larger tidal volume and lower respiratory rate.

Ventilator Associated Pneumonia

Special consideration must be taken to ensure that patients who require mechanical ventilation do not develop ventilator associated pneumonia (VAP). This is especially important in obese subjects, due to the preexisting decreased lung volumes and impairment in gas exchange.

Published reports indicate an increased incidence of specific complications in obese patients, including VAP. Clinicians must increase awareness with regard to prevention, diagnosis, and early treatment of VAP. Although it may be difficult to reduce the duration of mechanical ventilation, and thus decrease risk of VAP, there are other preventive strategies that may be used. A recent systematic review of strategies for the prevention of VAP recommends that clinicians consider the following: nursing in the semirecumbent position, sucralfate rather than H₂-antagonists in patients at low-to-moderate risk for gastrointestinal bleeding, aspiration of subglottic secretions, and oscillating beds.²⁵ VAP may not fully explain the excess mortality rate associated with obesity further research is needed to explore and understand the true correlation between the two.

Extubation Care of the Obese Patient

As the prevalence of obesity increases, more patients requiring hospital and surgical care will be obese. Postoperative complications are more frequent among the obese population, specifically surgical site infection and atelectasis. Along with increased intraabdominal pressure and venous stasis in obese individuals, there is a link between perioperative deep venous thrombosis, pulmonary embolism and obesity. Surgical procedures which involve prolonged immobility are associated with greater risk. Obese patients typically encounter more atelectasis in the postoperative period than non-obese patient. Abdominal or thoracic operations are a significant risk to obese patients. Atelectasis has been found in up to 45% of obese patients following upper abdominal surgery.²⁶ Early ambulation is vital in all obese patients to reduce the risk of thrombosis and pulmonary dysfunction. To encourage earlier ambulation specially designed abdominal binders for the larger patient may be used.

Obese patients with asthma or COPD are at enormous risk of perioperative respiratory complications. In patients with OSA, preoperative initiation and perioperative use of continuous airway pressure can reduce hypercarbia, hypoxemia, and pulmonary artery vasoconstriction and thus decrease the incidence of pulmonary complications.

Conclusion

The obesity epidemic poses many challenges to health professionals. An important challenge is to educate clinical of

all disciplines regarding the physiologic effects of obesity, thus reducing complications associated with hospitalization and any further respiratory impairment.

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- Explain the difference between actual body weight and predicted body weight as it relates to tidal volumes during mechanical ventilation.
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- 1: According to the CDC, morbid obesity refers to a body mass index kg/m² greater than:
 - a. 40
 - b. 18
 - c. 36
 - d. 29
- 2: With each unit increase in BMI, clinicians can estimate a decrease in VC, TLC, and RV of approximately:
 - a. 5%
 - b. 0.5%
 - c. 2.5%
 - d. 7%
- 3: Atelectasis has been found in up to 45% of obese patients following upper abdominal surgery.
 - a. True
 - b. False
- 4: Patients with obesity are high risk for aspiration due to:
 - a. Elevated intraabdominal pressure
 - b. Elevated gastric volume
 - c. Low pH of gastric contents
 - d. All of the above

- 5: During auscultation of the chest, wheezing in obese patients is always due to asthma.
 - a. True
 - b. False
- 6: The number of people in the US die each year as the result issues related to obesity is:
 - a. 100,000
 - b. 400,000
 - c. 25,000
 - d. 1 million
- 7: Tidal volume during mechanical ventilation should be based on:
 - a. PaO₂/FiO₂ ratio (P/F)
 - b. Predicted Body Weight (PBW)
 - c. Peak Inspiratory Pressure (PIP)
 - d. Actual Body Weight (ABW)
- 8: How much more oxygen at rest do obese subjects consume compared to those who are not obese:
 - a. 10%
 - b. 50%
 - c. 25%
 - d. 35%

- 9: Obese patients have a reduced Functional Residual Capacity (FRC).
 - a. True
 - b. False
- 10: Typically, PEEP values that are required to maintain oxygenation in obese patients can be:
 - a. 10 cmH₂O
 - b. 15 cmH₂O
 - c. 20 cmH₂O
 - d. 8 cmH₂O
- 11: The most serious complication (s) in the obese patient with a tracheostomy tube is:
 - A. Cuff leakage
 - B. Accidental decannulation
 - C. Tube obstruction
 - D. All of the above
- 12: The growth of *Candida* spp in the obese patient with a tracheostomy occurs because of:
 - A. irritation in the stoma site
 - B. tube impingement on the posterior wall of the trachea
 - C. warm, moist folds in the neck
 - D. mucus plug as a result of a partial dislodgement of the tube

Mark your answers with an X in the box next to the correct answer

What is the highest degree you have earned (circle one) ?

1. Diploma 2. Associate 3. Bachelor's
4. Master's 5. Doctorate

Indicate to what degree you met the objectives for this program: Using 1 = strongly disagree to 6 = strongly agree rating scale, please circle the number that best reflects the extent of your agreement to each statement.

	Strongly Disagree			Strongly Agree		
	1	2	3	4	5	6
1. Describe the physiological effects of obesity on the respiratory system in regards to lung volumes, airway management, and gas exchange.						
2. Explain the difference between actual body weight and predicted body weight as it relates to tidal volumes during mechanical ventilation.						
3. Describe the strategies to prevent complications in the obese patient with a tracheostomy						
4. Please indicate your agreement with this statement. "The content of this course was presented without bias of any product or drug."						

	A	B	C	D		A	B	C	D
1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	9	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	11	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	12	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	13	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	14	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	15	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	16	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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/12