Airway Management in the Obese Patient

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KEYWORDS

• Obesity • Airway management • Noninvasive ventilation
• Tracheostomy • Intubation

Obesity is a serious disorder and an increasing problem all over the world.[1] During the past several decades, the worldwide prevalence of obesity has steadily risen, with the greatest increase occurring in the United States.[2] The incidence of obesity has doubled in adults and tripled in children in the United States over the past 30 years; more than 60 million adults and 9 million children aged 6 to 19 years are obese or overweight.[3] Furthermore, the prevalence of extreme obesity (body mass index [BMI] >40) has seen the greatest growth this past decade.[4] This increase was seen in both sexes, all racial/ethnic groups, all age groups, and all education levels.[5] With such global epidemic, the presentation of an acutely ill or injured morbidly obese patient is currently a common occurrence. Obese patients may present also for an elective procedure, for bariatric surgery, or for obstetric anesthesia or analgesia. Expertise in airway management becomes an important skill for any health care provider involved in the care of these patients. The main body of this review will discuss strategies for airway assessment before intubation, controversies surrounding airway management, and approach to safe extubation in this population. The article will also address the role of noninvasive ventilation in the management of obese patients (other than sleep apnea) and practiced techniques for temporary tracheostomy placement in critically ill obese patients.

AIRWAY MANAGEMENT

A number of studies have suggested that obesity increases the risk of perioperative respiratory complications and complicates airway management.[6] A BMI greater than 26 kg/m^2 results in a 3-fold increase in difficult ventilation via a mask[7] and in a 10-fold increased incidence of difficult endotracheal intubation.[8] Despite the lack of outcome data, a thorough preoperative assessment has been strongly recommended before any elective procedure in a morbidly obese patient. Review of medical records for coexisting comorbidities (including hypertension and cardiovascular disease, type 2 diabetes, and osteoarthritis) and previous anesthesia reports for evidence of difficulty with tracheal intubation is now considered a routine preoperative assessment. Questions relating to symptoms of daytime drowsiness, snoring, frequent awakenings, and periods of apnea during sleep are sought for the presence of sleep apnea. When present, these patients may have a diminution of the pharyngeal space secondary to fat deposition in the pharyngeal wall,[9] which can make airway access and mask ventilation difficult. In addition, obstructive sleep apnea (OSA) has important implications for use of sedatives and opiates in the perioperative period.[10] Unfortunately, most morbidly obese surgical patients have not had a polysomnographic study to confirm the diagnosis.[11]

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The key to proper airway management in obese patients is anticipation of difficulty, adequate preparation (patient and equipment), and a detailed plan of action should problems arise. Various factors should be optimized including positioning of the obese patient, preoxygenation, intubating devices, and knowledge of alternate airway tools.

Positioning the Morbidly Obese Patient

Because repositioning a morbidly obese patient may be impossible if difficulties during laryngoscopy and/or intubation are encountered, careful patient positioning and choice of airway management are vitally important. Classic teaching has been to position the patient in the "sniffing" position, or supine with moderate head elevation and atlanto-occipital extension.[12] The sniffing position was first described by Jackson[13] and is believed to align the oral, pharyngeal, and laryngeal axes for a direct view of the glottic opening. Although the sniffing position is advantageous not only for laryngoscopy but also for mask ventilating the patient's lungs before tracheal intubation, morbidly obese patients are more prone to hypoxemia in the supine position than individuals of normal weight owing to reduction in expiratory reserve volume. This is attributed to the mechanical effect of increased fat within the chest wall, abdominal wall, and abdomen, which combine to compress the thoracic cage, diaphragm, and lungs. The resultant impairment of diaphragmatic descent reduces functional residual capacity (FRC), which in turn increases airway resistance and worsens ventilation perfusion mismatch.[14] An alternative approach is to place the obese patient in the "ramped position" by using folded blankets, stacked under the patient's upper body, neck, and head, to elevate the head. According to Collins and coworkers,[15] the "ramped" position improved the laryngeal view when compared with a standard "sniff" position in morbidly obese patients undergoing elective bariatric surgery. Furthermore, Dixon and colleagues[16] noted 23% improvement in mean arterial oxygen tension when these patients were placed in a 25° reverse Trendelenburg position. However, attaining the optimum position in each patient can be tedious, as it requires adding or removing blankets while repositioning the patient each time. Use of other devices including a commercially available foam pillow (Troop Elevation Pillow, Mercury Medical, Clearwater, Florida) to achieve this position has been described in recent literature.[17,18] Head-up position also can be achieved by a simple maneuver of configuring the operating room table, similar to a reclining chair with the back or trunk portion of the table up.[19] With the patient lying on the table, the electronic table controls can be used to flex the table at the trunk-thigh hinge and raise the "back" or "trunk" section of the table up as necessary to achieve the optimum position. This can be done with or without the headpiece at the head end of the table.

Preoxygenation

In patients of normal weight, a forced vital capacity ventilation for eight breaths during 60 seconds with high flows of oxygen 100% was shown to achieve adequate denitrogenation and slower desaturation during apnea compared with the usual 3 minutes tidal-volume ventilation technique.[20] Obesity, however, impairs seriously the effectiveness of preoxygenation because of a decrease in FRC secondary to cephalad diaphragmatic displacement.[21] The adoption of the sitting position for preoxygenation with eight deep breaths of ventilation over 60 seconds can increase the apnea tolerance by almost 1 minute compared with the same maneuver performed with the patient in the supine position.[22] Obviously, the utility of this approach is limited to patients who are scheduled for elective surgery. Other studies have examined the impact of different strategies known to increase the FRC on the effectiveness of preoxygenation.[23] Cressey and colleagues[23] found a non–statistically significant increase of 37 seconds in the time to desaturate to 90% when 7.5 cm H_2O continuous positive airway pressure (CPAP) was applied during preoxygenation to morbidly obese women. Although this level of CPAP might be insufficient to effectively shift the abdominal content, the application of CPAP at 10 cm H_2O for 5 minutes during the administration of oxygen followed by ventilation via face mask with positive end-expiratory pressure at 10 cm H_2O for 5 minutes was effective in improving oxygenation and in reducing atelectasis as assessed by CT scan.[24] Similar findings were reported by Gander and coworkers[25] who randomized 30 morbidly obese patients to receive positive end expiratory pressure (PEEP) during induction or to no PEEP. The group who received 100% O_2 through a CPAP (10 cm H_2O) for 5 minutes followed by pressure control ventilation for another 5 minutes until tracheal intubation had longer nonhypoxic apnea and less atelectasis formation. More recently, El-Khatib and colleagues[26] confirmed these observations by showing that the application of noninvasive bilevel positive airway pressure (BiPAP) (17/7 cm H_2O) in morbidly obese patients undergoing urgent surgery improved oxygenation significantly before rapid sequence induction of anesthesia.

Mask Ventilation and Tracheal Intubation

In an attempt to standardize airway management, the American Society of Anesthesiology issued a consensus in 1993 that was updated in 2003 in which the Society defines difficult airway as "the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation or both."[3,27] Difficult mask ventilation is defined as the inability of an unassisted anesthesiologist to maintain the measured oxygen saturation as measured by pulse oximetry greater than 92% or to prevent or reverse signs of inadequate ventilation during positive-pressure mask ventilation under general anesthesia. Difficult intubation has been defined by the need for more than three intubation attempts or attempts at intubation that last more than 10 minutes.

While the rate of difficult mask ventilation (DMV) in the general population ranges from 0.07% to 15.00%,[8,28,29] the incidence of DMV in obese patients has been rarely assessed in studies related to airway management, and no previous specific studies regarding difficulty with mask ventilation alone have been performed. Hence, an initial step in the management of the obese patient requiring invasive ventilation is to determine the risk for difficult mask ventilation. Difficult mask ventilation may occur before attempting intubation or may occur after intubation failure.[30] Five criteria have been identified as independent risk factors for DMV: age older than 55 years, body mass index greater than 26 kg/m^2, lack of teeth, presence of beard, and history of snoring.[7] The presence of obesity plus another risk factor indicates a high likelihood of DMV. Similar predictors are provided by the mnemonic MOANS (mask seal, obesity, age >55 years, no teeth, and stiffness),[31] although there is no clear correlation between each of these attributes and the degree of difficulty.

By the same token, the predictive role of obesity as an independent risk factor for difficult intubation remains controversial. Part of the problem in determining the incidence of airway difficulty stems from the various ways of defining what constitutes a "difficult intubation." In two series of morbidly obese patients undergoing upper abdominal surgery, the incidence of difficult intubation was 13% and 24% respectively.[32,33] Another study examining 1833 intubations among all patients undergoing general anesthesia revealed that obesity provided a 20.2% predictive value of difficult intubation compared with patients with normal body mass index.[34] Additionally, a threefold increase in difficult laryngoscopy has been reported among obese patients compared with patients with normal BMI. In the Australian Incident Monitoring Study, limited neck mobility and mouth opening accounted for most cases of difficult intubation in obese subjects.[29] Naguib and colleagues[35] added to the preceding list a short sternomental distance, a receding mandible, and prominent teeth as potential causes for difficult intubation. Others identified neck circumference greater than 40 cm and a Mallampati score of 3 or more as sole predictors of difficult intubation in morbidly obese patients.[36] However, the magnitude of obesity does not always correlate with difficulty in managing the airway. Preoperative bedside screening tests including the Mallampati oropharyngeal classification,[37] as well as thyromental and sternomental distances,[38] have been shown to be neither sensitive nor specific enough for routine clinical use.[34] Gaszynski[39] was unable to validate any of these characteristics in a group of 87 morbidly obese patients undergoing elective surgery. In fact, all morbidly obese patients with BMI greater than 50 kg/m^2 were intubated by first attempt. Furthermore, OSA, a well-known risk factor for difficult laryngoscopy in lean individuals,[40,41] was not associated with difficult intubation in the obese patients. A recent study[42] found that the Extended Mallampati Score[43] and the diagnosis of diabetes mellitus may prove superior to the modified Mallampati classification in the prediction of difficult laryngoscopy in the morbidly obese population (**Box 1**). Glycosylation of joints owing to chronic hyperglycemia can result in limited mobility, which may also affect the cervical and laryngeal areas.[44] The study was limited however by the heterogeneity of examiners and laryngoscopists and the subjective assessment of airway examinations.

It was suggested that the poor predictability of neck circumference in estimating difficult intubation in obese subjects might be related to the unequal distribution of fat and soft tissue at various topographic regions within the neck.[45] The use of MRI or CT scans to quantify the amount of soft tissue at the level of the vocal cords and suprasternal notch has been proposed as a possible diagnostic imaging to predict difficult laryngoscopy.[46] However, MRI and CT scans are costly and may not be always be practical in this population. In the past few years, several studies have relied on ultrasound to predict difficult intubation.[47] Ezri and colleagues[48] suggested that abundance of fat tissue at the anterior neck region, as measured by ultrasound, was indicative of difficult laryngoscopy, but Komatsu and coworkers[49] could not substantiate these findings when tested on 64

Box 1
The Mallampati airway classification system

Original Mallampati test

Grade 1: Faucial pillars, soft palate, and uvula can be visualized

Grade 2: Faucial pillars and soft palate can be visualized, but uvula is masked by base of the tongue

Grade 3: Only soft palate can be visualized

Modified Mallampati test

MMP examination conducted with the patient sitting upright, the head in neutral position, and the tongue maximally protruded

Class 1: Soft palate, fauces, uvula, pillars seen

Class 2: Soft palate, fauces, uvula seen

Class 3: Soft palate, base of uvula seen

Class 4: Soft palate not visible at all

Extended Mallampati score

MMP examination conducted with craniocervical extension

Class 1: Entire uvula clearly visible

Class 2: Upper half of uvula visible

Class 3: Soft and hard palate clearly visible

Class 4: Only hard palate visible

obese patients (BMI >35 kg/m^2) undergoing elective surgery. Because of a low predictive power of these constructed models and techniques, preplanned strategy remains central to safe and successful intubation.

Awake Intubation and Videolaryngoscope

Awake intubation using a flexible fiber-optic bronchoscope is considered the method of choice when treating an obese patient with an anticipated difficult airway;[50] however, the significant equipment costs and skill maintenance issues have limited the widespread adoption of this approach. One recent survey reported that only 59% of US anesthesiologists are proficient in fiber-optic intubation.[51] Various rigid indirect fiber-optic and video-based intubation devices have been developed as alternatives to flexible fiber-optic bronchoscope intubation and direct laryngoscopy in the difficult airway. Although the application of these devices has yet to be determined in the overall airway management of the obese patient, the use of a videolaryngoscope for intubation may allow a better visualization of the glottic anatomy, thereby improving the intubation conditions. In a randomized study of 80 morbidly obese patients undergoing bariatric surgery, Marrel and coworkers[52] reported that the grade of laryngoscopy, as assessed by the Cormack and Lehane scale, was significantly lower compared with the direct vision. The minimal arterial oxygen saturation (SpO2) reached during the intubation was also higher with the videolaryngoscope but it did not attain statistical significance. Hirabayashi and colleagues[53] demonstrated similar improvement in glottic opening in four morbidly obese patients using GlideScope in comparison with the Macintosh direct laryngoscope. Recently, a large study consisting of 318 morbidly obese patients scheduled for elective surgery confirmed that video-assisted tracheal intubation devices (LMCA CTrach and the Airtraq laryngoscope) allowed optimization of arterial oxygenation, and early definitive airway as compared with the conventional Macintosh laryngoscope.[54]

Rapid Sequence Intubation

Rapid sequence induction with cricoid pressure remains one of the most common intubation techniques for morbidly obese patients.[55] An early form of rapid sequence induction and intubation (RSI) was described in the early 1950s.[56] The technique was subsequently modified and the most noticeable being the introduction of cricoid pressure by Barry Sellick in 1961.[57] The technique consists of seven distinct steps designed to minimize the risk of regurgitation of gastric contents into the lungs (**Box 2**). During the procedure, cricoid pressure is applied immediately after loss of consciousness and no bag or mask ventilation is performed before the first laryngoscopy. Although these actions seem simple and easy to follow, there has been no randomized trial assessing the efficacy of RSI in morbidly obese patients.

Box 2
Seven steps of rapid sequence intubation

1. Preparation
2. Preoxygenation
3. Pretreatment
4. Paralysis (with induction)
   Induction
   Cricoid pressure
   Paralytic
5. Pass the tube
6. Proof of placement
7. Postintubation management

The widespread application of RSI has pushed some critics to question its safety in the obese patients. First, there is a continuous debate about whether obese patients are at increased risk for acid aspiration syndrome. Available data on gastric pH, volume, and barrier pressure in morbidly obese patients are conflicting. A gastric pH less than 2.5 and a residual gastric fluid volume of 25 mL or higher are critical factors in the risk for aspiration-induced lung injury. Vaughan and colleagues[58] found that more than 70% of obese patients had a combination of gastric volumes 25 mL or more and pH 2.5 or lower compared with only 5% in nonobese individuals. Similar observations were noted by Fisher and colleagues.[59] Of 30 morbidly obese patients presenting for bariatric surgery evaluation, 11 had prolonged esophageal acid exposure with pH 4 or lower for more than 5% of observed time. Zacchi and coworkers[60] have challenged these contentions, showing that obese patients without symptoms of gastro-esophageal reflux have a resistance gradient between the stomach and the gastro-esophageal junction similar to that in nonobese subjects. The rate of gastric emptying was also no different in obese and nonobese patients.[61] In addition, no correlation could be established between gastric volume and fasting duration.[62] If any, a substantially *lower* incidence of combined high gastric volume and low pH was found in fasted, obese patients compared with lean patients.[63] Second, the use of cricoid pressure as a measure against passive regurgitation did not prevent aspiration completely[64,65] and there is little evidence that it improved patient outcome.[66] Garrard and colleagues[67] reported a reduction in lower esophageal sphincter pressure during the application of cricoid pressure in anesthetized patients. Moreover, CT and MRI studies on nonanesthetized volunteers have shown that in up to 50% of the subjects the esophagus was viewed lateral to the cricoid ring and that cricoid pressure displaced it more laterally.[68,69] Cricoid pressure can also have negative hemodynamic consequences. The application of cricoid pressure in healthy adult patients has been shown to increase systolic arterial blood pressure and to cause a significant rise in heart rate.[70] Even when performed correctly, cricoid pressure may interfere with laryngeal mask airway insertion, laryngoscopy, and success in intubation.[71] Haslam and colleagues[72] studied the effect of gradual increment of cricoid pressure on laryngoscopy on 40 patients undergoing elective surgery including obese individuals. Five subjects with a good initial view (anteroposterior length of the rima glottidis >5 mm) showed a marked deterioration in laryngoscopic view as cricoid pressure increased; in three of these subjects laryngoscopic view progressed to obscure the larynx completely at a force of 30 N, 40 N, and 60 N, respectively. Third, the process of protecting the lungs by doing a rapid sequence induction adds risk to the airway management of the morbidly obese patient. Because of the speed and commitment associated with this technique, a failed intubation offers no opportunity for the morbidly obese patient to resume spontaneous ventilation for anywhere from 5 to 15 minutes, depending on the choice of neuromuscular blocking drug. In addition, if ventilation via the face mask after anesthetic induction proves to be difficult, it is common for the morbidly obese patient to have rapid arterial oxygen desaturation of blood oxygen content as detailed previously. Thus, avoiding a rapid sequence induction technique affords additional time to use maneuvers such as sedated fiber-optic intubation while maintaining spontaneous ventilation, or induction of anesthesia, and establishing ventilation via mask before administering any neuromuscular drug.

The optical stylet combined with RSI laryngoscopy is a novel fiber-optic technique for the potentially difficult laryngoscope obese patient. Although RSI flexible fiber-optic intubation has been described, it requires significant expertise and working at arm's length with a 60 cm-flexible instrument.[73] By comparison, the optical stylet is shaped and positioned as a standard stylet, and its use fiber-optically involves minimal movement to switch from a direct view of its distal tip to a fiber-optic view through the eyepiece.[74] It offers the option of transitioning to fiber-optic intubation within the insertion time frame of a standard stylet on the first laryngoscopy.

Extraglottic Devices

Many different devices for airway management have been recommended by the American Society of Anesthesiologists (ASA) difficult airway algorithm.[75] The standard laryngeal mask airway (LMA) has been used to facilitate blind endotracheal intubation in numerous situations where laryngoscope and conventional intubations have been difficult (**Fig. 1**). Because of the reduced chest compliance and sheer mass of the chest wall in obese patients, higher inflation pressures are required to ventilate such patients. Such high pressures may preclude the use of the LMA for ventilation. Instead, the intubating laryngeal airway mask (ILMA) is considered a superior alternative. In 118 consecutive morbidly obese patients, Frappier and coworkers[76] achieved successful

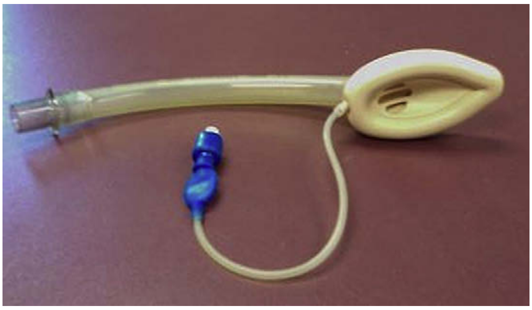

Fig. 1. The laryngeal mask airway.

tracheal intubation of 96.3% with the ILMA. These results were later duplicated in 50 morbidly obese with a comparable success rate of 96%.[77] There was also lower overall difficulty airway management scores as measured by the visual analog scale in obese patients as compared with lean patients. The preponderance of adipose tissue, predominantly in the lateral pharyngeal walls, is thought to guide the ILMA into place during its descent into the pharynx and stabilize its position after cuff inflation.

The esophageal tracheal combitube (ETC) is another alternative for rescue ventilation in the patients with difficult airway (**Fig. 2**). Two case reports reported successful ventilation with the ETC in grossly obese patients with bull neck.[78,79] The importance of the ETC in the field of airway management is that it represents one of the few extraglottic devices, which may provide effective protection to those at risk for aspiration.[80] However, the use of ETC can be associated with serious complications, including esophageal laceration, pneumomediastinum, and pneumoperitoneum.[81]

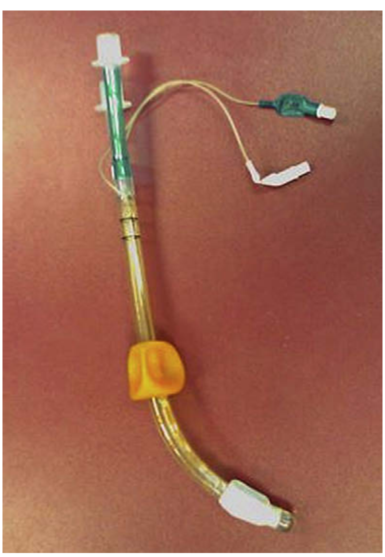

Fig. 2. The esophageal tracheal combitube.

New extraglottic devices have been introduced in recent years, many of which may also play an important role in rescuing a failed airway. Several recent reports have detailed successful use of the Laryngeal Tube (VBM Medizintechnik, Sulz, Germany),[82] the CobraPLA (Engineered Medical System, Indianapolis, Indiana)[83] and the PAxpressTM (Vital Signs Inc., Totowa, New Jersey)[84] in providing effective ventilation and oxygenation in patients under a variety of difficult circumstances. Whether these devices will receive acceptance equal to that of the ILMA and ETC in the obese patient with difficult airway is unknown. The choice of devices will ultimately depend on experience and clinical judgment.

EXTUBATION

The process of extubating a morbidly obese patient can be a daunting task. In normal-weight patients, the practice of extubating the trachea soon after surgery followed by assisted mask ventilation until the patient is fully awake may not be practical in an obese patient. If the obese patient was difficult to intubate, extreme care should be taken at extubation, as reintubation may be more difficult than the original procedure. Because patients with morbid obesity are at higher risk for postextubation stridor,[85] the cuff leak test has been suggested as a tool for identifying laryngeal edema. Initial inconsistencies in the reproducibility of this technique have cast doubts on its utility.[86,87] With the widespread use of ultrasonographic imaging in the management of critically ill patients, noninvasive examination of the vocal cords and the larynx became more accessible. The use of laryngeal ultrasound to detect patients at risk of postextubation stridor, by evaluating peri-cuff airflow has been recently described. Using real time laryngeal ultrasonography, Ding and colleagues[88] showed that a lower air column width during balloon deflation was a good predictor of postextubation stridor. Although the study did not include the BMI of patients who participated in the trial, the noninvasive nature of the test may still prove of utility in this population pending validation of the data in obese patients.

Ultrasound imaging has been advocated also as a novel technique for predicting extubation outcome. Because there is a direct correlation between respiratory muscle endurance and excursions of the diaphragm, liver, and spleen, measurement of liver and spleen displacement (MLSD) during spontaneous breathing trial may prove useful in assessing extubation readiness.

Using a cutoff value of 1.1 cm for MLSD between the end of inspiration and the end of expiration, the sensitivity and specificity to predict successful extubation were 84.4% and 82.6%, respectively.[89] Whether these parameters hold true for patients who are obese remains to be seen.

In approaching tracheal extubation in obese patients, a reverse Trendelenburg position is recommended to optimize ventilation, decrease the risk of reflux, and access to the airway if reintubation becomes necessary. Placement of an airway exchange catheter[90] to retain a conduit for possible reintubation may prove to be useful for obese patients at risk for difficult intubation. The catheter allows for gas exchange either by jet ventilation or oxygen insufflation until the patient is deemed stable. Although the utility of this catheter has yet to be proven in obese patients, the airway exchange catheter is considered effective and safe with low risk of aspiration or barotrauma and may obviate the need for nasal cannula or facemask following tracheal extubation.[91]

After full recovery, patients should be informed and counseled regarding problems encountered and its relevance to further airway management. Clear description regarding the problem and subsequent solution should also be kept in the hospital records.

NONINVASIVE VENTILATION

Treatment of acute hypercapnic respiratory failure with noninvasive ventilation (NIV) has been proposed as a means of avoiding invasive mechanical ventilation and the associated complications. Although two consensus conferences pointed out that the use of NIV for treatment of acute respiratory failure in the morbidly obese is a relative contraindication,[92,93] earlier studies reported successful application of NIV in morbidly obese patients with hypercapnic respiratory failure.[94–96] A more recent investigation reviewed the outcome of 50 morbidly obese patients admitted to a medical intensive care unit with acute respiratory failure requiring ventilatory assistance.[97] A total of 33 patients were treated with NIV of whom 64% avoided invasive mechanical ventilation. Patients successfully treated with NIV had a significantly lower BMI, demonstrated improvement in gas exchange, and had a shorter hospital stay and a lower mortality. In contrast, patients who failed a trial of NIV and those who required invasive mechanical ventilation demonstrated a longer intensive care unit and hospital length of stay and higher mortality (31%). In the absence of randomized controlled trials, these case series have shown that NIV is safe in this population and may be associated with improvements in arterial blood gas measurements, thereby providing support for its application. The benefit of NIV in morbidly obese patients stems from the significant unloading of inspiratory muscles. Using a full face mask with the application of bilevel ventilation in 18 subjects with a BMI of 40 kg/m^2 or higher, Pankow and colleagues[98] showed a drop of 46% in diaphragmatic activity. Subsequently, Rabec and colleagues[99] successfully treated 39 of 41 morbidly obese patients with acute respiratory failure using BiPAP. All 39 patients were discharged home without need for tracheal intubation. Of note, the application of NIV in these patients required inspiratory pressures in excess of 15 cm H_2O owing to the reduced lung volumes and increased airway resistance.[100,101]

Numerous studies have highlighted the complexity of respiratory management of critically ill obese patients during the period following liberation from mechanical ventilation.[102,103] The development of respiratory instability, episodic desaturation in the supine position, and the respiratory depressant effects of sedatives and opioid analgesia predispose these patients to prolonged periods of apneas, hypoxemia, and severe hypercapnia culminating in respiratory failure. Review of the literature puts the rate of reintubation postextubation in severely obese patients at 8% to 14% among patients undergoing mechanical ventilation for more than 48 hours.[104,105] Earlier investigations suggested that the prophylactic use of NIV in morbidly obese patients during the first 24 hours postoperatively reduced pulmonary dysfunction after gastroplasty and accelerated reestablishment of preoperative pulmonary function. Joris and colleagues[106] demonstrated that the application of BiPAP set at 12 and 4 cm H_2O improved significantly the peak expiratory flow rate, the forced vital capacity, and the oxygen saturation on the first postoperative day. These improvements are attributed to a combined effect of improved lung inflation, prevention of alveolar collapse, and reduced inspiratory threshold load. Similar physiologic effects are thought to be responsible for the reduced rate of respiratory failure postextubation. In a nonrandomized concurrent prospective study of 62 morbidly obese patients treated in a medical ICU, El Solh and colleagues[107] reported a 16% absolute risk reduction in the rate of respiratory failure when NIV was instituted immediately postextubation. Subgroup analysis of hypercapnic patients showed reduced hospital mortality in the NIV group compared with historic controls matched for age, BMI, and Acute Physiologic and Chronic Health Evaluation II score. Hence, early intervention with noninvasive ventilation may be effective in averting respiratory failure before the development of respiratory distress and may be responsible for decreasing mortality in selected patients with chronic hypercapnia.

TRACHEOSTOMY

Tracheostomy continues to be the standard procedure for management of long-term ventilator-dependent patients. It presents several advantages over endotracheal intubation, including lower airway resistance, smaller dead space, less movement of the tube within the trachea, greater patient comfort, and more efficient suction.[108,109] Despite the controversy as to the proper time to perform tracheostomy, prospective studies suggest that there may be a benefit to early tracheostomy.[110] Yet, in the absence of valid evidence that is based on randomized controlled trials, the decision to place a tracheostomy is made on the consideration of the benefits versus risks of the procedure.

Surgical Tracheostomy

The overall complication rate of surgical tracheostomy in obese patients is estimated at 25%, most of which are minor.[111] Serious complications occur in 10% and are usually life threatening.[111] In patients who require tracheostomy, morbidly obese patients present a unique surgical challenge because of increased submental and anterior cervical adipose tissue. The initial goal of securing a stable airway can be compromised by the size discrepancy and curvature mismatch between a standard-size tracheostomy tube and the increased distance between skin and trachea. Standard tracheotomy tubes are typically too short and angulated. Consequently, they are more likely to get occluded or dislodged. When obstruction of the tracheotomy tube occurs in the first 24 hours postoperatively, it is usually the result of tube impingement on the posterior tracheal wall, partial displacement into the mediastinum, a blood clot, or a mucous plug. When one of these complications occurs in the morbidly obese patient who is lying supine and partially sedated, hypoxemia develops rapidly as a consequence of reduced expiratory reserve volume.[112] To avert anoxic encephalopathy, immediate resuscitation is required. As a result, it is recommended that morbidly obese patients be monitored in an ICU setting for at least 72 hours following a surgical tracheostomy. Nonetheless, the risk of developing this complication persists beyond this time frame. Submental fat deposition that may reach below the sternal notch could also occlude the outer opening of the standard tracheostomy, rendering any oxygenation extremely limited or nonexistent. Simmons[113] recommended the application of an elastic bandage or a Barton bandage to move the chin out of the way. Others have considered the use of an extension attached to the outer opening.[114]

Accidental decannulation of tracheostomy tube in morbidly obese patients can be also life threatening in the setting of critical care illness. Morbidly obese patients with short, thick necks usually have too much soft tissue between the trachea and the skin. Unsuccessful blinded reinsertion attempts may cause tube misplacement in the pretracheal fascia with resultant tracheal compression and respiratory arrest. Some surgeons advocate performing a Björk flap at the time of surgery to prevent tube misplacement in the pretracheal fascia; however, this technique may be associated with higher incidence of tracheal stenosis postdecannulation.[115] Others prefer[116] a cervical lipectomy in combination with tracheostomy. Whether morbidly obese patients will benefit from the application of these techniques to reduce the rate of extratracheal placement of tracheostomy tube is unclear because there are no studies to date providing a conclusive answer.

Percutaneous Dilatation Tracheostomy

Percutaneous dilatation tracheostomy (PDT) is a widely used and accepted method in ICUs for long-term ventilation of critically ill patients. The technique was first described in 1985 by Ciaglia and colleagues[117] as an alternative to standard tracheostomy. The perceived advantages of PDT include its speed, simplicity, and cost, plus the fact that PDT obviates the need to transport critically ill patients outside of the ICU.[118] Traditionally, obesity has been considered a relative contraindication to the performance of PDT because, in these patients, conditions in the neck can make it difficult to properly identify anatomic landmarks.[119] Complications were related to imprecise paramedian puncture of the trachea or the formation of a paramedian stoma with potential lesions of the lateral tracheal wall.[120] However, there is also no concrete evidence supporting the superiority of standard tracheostomy in this patient group. A recent retrospective study that analyzed perioperative complications of standard tracheostomy in 427 critically ill patients found that morbidly obese patients were 4.4 times more likely than nonobese patients to suffer complications associated with standard tracheostomy (25% versus 14%, P = .03).[111] In comparison, the rate of PDT complications in morbidly obese patients

Table 1
Studies evaluating percutaneous dilatation tracheostomy in obese patients

Authors	Year of Publication	Study Design	No. Obese Patients	Mean BMI or BMI range, kg/m^2	PDT	Complication Rate, %
Aldawood et al. [121]	2008	Prospective	50	30	50	12.0
Heyrosa et al.[122]	2006	Retrospective	143	35–105	89	5.6
Byhahn et al.[123]	2005	Case control	73	27.5–64.3	73	43.8
Mansharamani et al.[124]	2000	Case series	13	28.1–67.0	13	7.7
Scott and Leigh[125]	2000	Case report	3	43.0–48.1	3	Not stated
Unwin et al.[126]	2000	Case report	1	58	1	Not stated

Abbreviations: BMI, body mass index; PDT, percutaneous dilational tracheostomy.

ranged from 5.6% to 43.8% (**Table 1**). Recently, a meta-analysis of 23 studies that included 2237 patients who had PDT examined the incidence of complications of PDT with and without fiber-optic bronchoscopy assistance.[127] In the blind-PDT group, the incidence of complications was 16.8%, whereas in the fiber-optic bronchoscopy–assisted PDT group, the incidence of complications was 8.3% ($P<.001$). Various authors[128,129] have proposed the use of ultrasonography as an alternative to fiber-optic bronchoscopy support to guide the procedure in real time or as a complementary tool to evaluate the cervical anatomy before the puncture. Kollig and colleagues[130] found that ultrasound examination of the neck changed the puncture site in 24% of their patients. One case report of a morbidly obese patient reiterated the safety of ultrasound in localizing the site for PDT.[120] Neck thickness had no influence on ultrasonographic findings. Notwithstanding, PDT should be postponed in obese patients who are dependent on high positive end-expired pressure or who require an FIO_2 greater than 0.6 to maintain their oxygen saturation. In such cases, accidental endotracheal tube cuff rupture could result in grave hypoxemia before airtight ventilation is reestablished.

SUMMARY

Airway management of the obese patient represents a daunting task for health care practitioners. There are no reliable methods so far for determining in advance which patients may require alternative rescue devices for assisted intubation. A thorough evaluation and preparation for anticipated difficult airway including proper positioning, preoxygenation, and the immediate readiness of rescue ventilation devices are critical. Although laryngoscopy can be associated with a high degree of success, there is little margin for failure. Critical desaturation will be precipitous, and repeat laryngoscopy efforts carry significant risks. Early application of noninvasive ventilation in the postoperative period particularly in those with documented sleep apnea improves respiratory physiology and may prevent reintubation. For those patients with prolonged mechanical ventilation, percutaneous dilatation tracheostomy is safe and well tolerated when performed by experienced personnel.

REFERENCES

1. Organization WH. Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity 1998.
2. Mokdad AH, Ford ES, Bowman BA, et al. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. JAMA 2003;289:76–9.
3. Ogden CL, Carroll MD, McDowell MA, et al. Obesity among adults in the United States—no change since 2003–2004. NCHS data brief no 1. Hyattsville (MD): National Center for Health Statistics; 2007.
4. Vallejo M. Anesthetic management of the morbidly obese parturient. Curr Opin Anaesthesiol 2007; 20(3):175–80.
5. Freedman DS, Khan LK, Serdula MK, et al. Trends and correlates of class 3 obesity in the United States from 1990 through 2000. JAMA 2002;288: 1758–61.
6. Chung F, Mezei G, Tong D. Pre-existing medical conditions as predictors of adverse events in day-case surgery. Br J Anaesth 1999;83:262–70.
7. Langeron O, Masso E, Huraux C, et al. Prediction of difficult mask ventilation. Anesthesiology 2000;92: 1229–36.
8. El-Ganzouri AR, McCarthy RJ, Tuman KJ, et al. Preoperative airway assessment: predictive value of a multivariate risk index. Anesth Analg 1996;82: 1197–204.
9. Busetto L, Enzi G, Inelmen EM, et al. Obstructive sleep apnea syndrome in morbid obesity: effects of intragastric balloon. Chest 2005;128:618–23.
10. Gross JB, Bachenberg KL, Benumof JL, et al. American Society of Anesthesiologists Task Force on Perioperative Management. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: a report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea. Anesthesiology 2006; 104:1081–93.
11. Kaw R, Michota F, Jaffer A, et al. Unrecognized sleep apnea in the surgical patient: implications for the perioperative setting. Chest 2006;129: 198–205.
12. Bannister FB, Macbeth RG. Direct laryngoscopy and tracheal intubation. Lancet 1944;244:651–4.
13. Jackson C. The technique of insertion of intratracheal insufflation tubes. Surg Gynecol Obstet 1913;17:507–9.
14. Yap JC, Watson RA, Gilbey S, et al. Effects of posture on respiratory mechanics in obesity. J Appl Physiol 1995;79:1199–205.
15. Collins JS, Lemmens HJ, Brodsky JB, et al. Laryngoscopy and morbid obesity: a comparison of the “sniff” and “ramped” positions. Obes Surg 2004; 14:1171–5.
16. Dixon BJ, Dixon JB, Carden JR, et al. Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study. Anesthesiology 2005;102:1110–5.

17. Nissen MD, Gayes JM. An inflatable, multichambered upper body support for the placement of the obese patient in the head-elevated laryngoscopy position. Anesth Analg 2007;104:1305–6.
18. Wong AB, Moore MS. Positioning of obese patients in out-of-operating room locations. Anesth Analg 2007;104:1306.
19. Rao SL, Kunselman AR, Schuler HG, et al. Laryngoscopy and tracheal intubation in the head-elevated position in obese patients: a randomized, controlled, equivalence trial. Anesth Analg 2008; 107(6):1912–8.
20. Baraka AS, Taha SK, Aouad MT, et al. Preoxygenation: comparison of maximal breathing and tidal volume breathing techniques. Anesthesiology 1999;91:612–6.
21. Berthoud MC, Peacock JE, Reilly CS. Effectiveness of preoxygenation in morbidly obese patients. Br J Anaesth 1991;67:464–6.
22. Altermatt FR, Muñoz HR, Delfino AE, et al. Preoxygenation in the obese patient: effects of position on tolerance to apnoea. Br J Anaesth 2005;95(5): 706–9.
23. Cressey DM, Berthoud MC, Reilly CS. Effectiveness of continuous positive airway pressure to enhance pre-oxygenation in morbidly obese women. Anaesthesia 2001;56:680–4.
24. Coussa M, Proietti S, Schnyder P, et al. Prevention of atelectasis formation during the inducation of general anesthesia in morbidly obese patients. Anesth Analg 2004;98:1491–5.
25. Gander S, Frascarolo P, Suter M, et al. Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. Anesth Analg 2005;100:580–4.
26. El-Khatib MF, Kanazi G, Baraka AS. Noninvasive bilevel positive airway pressure for preoxygenation of the critically ill morbidly obese patient. Can J Anaesth 2007;54(9):744–7.
27. Caplan RA, Benumof J, Berry F. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2003;98:1269–77.
28. Asai T, Koga K, Vaughan RS. Respiratory complications associated with tracheal intubation and extubation. Br J Anaesth 1998;80:767–75.
29. Williamson JA, Webb RK, Szekely S, et al. Australian incident monitoring study: difficult intubation: an analysis of 2,000 incident reports. Anaesth Intensive Care 1993;21:602–7.
30. Crosby ET, Cooper RM, Douglas MJ, et al. The unanticipated difficult airway with recommendations for management. Can J Anaesth 1998;45:757–76.
31. Murphy M, Walls RM. Identification of the difficult and failed airway. In: Walls RM, Murphy MF, Luten RC, editors. Manual of emergency airway management. Philadelphia: Lippincott Williams and Wilkins; 2004. p. 70–2.
32. Buckley F, Robinson N, Simonowitz D, et al. Anesthesia in the morbidly obese patient: a comparison of anaesthetic and analgesic regimens for upper abdominal surgery. Anaesthesia 1983;38:840–51.
33. Cherit G, Gonzalez R, Borunda D, et al. Anesthesia for morbidly obese patients. World J Surg 1998;22: 969–73.
34. Voyagis G, Kyriakis K, Dimitriou V, et al. Value of oropharyngeal Mallampati classification in predicting difficult laryngoscopy among obese patients. Eur J Anaesthesiol 1998;15:330–4.
35. Naguib M, Malabarey T, Alsatli RA, et al. Predictive models for difficult laryngoscopy and intubation: a clinical, radiographic and three-dimensional computer imaging study. Can J Anaesth 1999;46:748–59.
36. Brodsky JB, Lemmens HJ, Brock-Utne JG, et al. Morbid obesity and tracheal intubation. Anesth Analg 2002;94:732–6.
37. Mallampati SR, Gatt SP, Gugino LD, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J 1985;32: 429–34.
38. Butler PJ, Dhata SS. Prediction of difficult laryngoscopy: an assessment of the thyromental distance and Mallampati predictive tests. Anaesth Intensive Care 1992;20:139–42.
39. Gaszynski T. Standard clinical tests for predicting difficult intubation are not useful among morbidly obese patients. Anesth Analg 2004;99:956.
40. Hiremath AS, Hillman DR, James AL, et al. Relationship between difficult tracheal intubation and obstructive sleep apnoea. Br J Anaesth 1998;80: 606–11.
41. Benumof JL. Obstructive sleep apnea in the adult obese patient: implications for airway management. J Clin Anesth 2001;13:144–56.
42. Mashour GA, Kheterpal S, Vanaharam V, et al. The extended Mallampati score and a diagnosis of diabetes mellitus are predictors of difficult laryngoscopy in the morbidly obese. Anesth Analg 2008; 107(6):1919–23.
43. Mashour GA, Sandberg WS. Craniocervical extension improves the specificity and predictive value of the Mallampati airway evaluation. Anesth Analg 2006;103:1256–9.
44. Riessell E, Orko R, Maunuksela EL, et al. Predictability of difficult laryngoscopy in patients with long-term diabetes mellitus. Anaesthesia 1990;45: 1024–7.
45. Gonzalez H, Minville V, Delanoue K, et al. The importance of increased neck circumference to intubation difficulties in obese patients. Anesth Analg 2008;106(4):1132–6.

46. Caballero P, Alvarez-Sala R, Garcia-Rio F, et al. CT in the evaluation of the upper airway in healthy subjects and in patients with obstructive sleep apnea syndrome. Chest 1998;113:111–6.
47. Hatfield A, Bodenham A. Ultrasound: an emerging role in anaesthesia and intensive care. Br J Anaesth 1999;83:789–800.
48. Ezri T, Gewurtz G, Sessler DI, et al. Prediction of difficult laryngoscopy in obese patients by ultrasound quantification of anterior neck soft tissue. Anaesthesia 2003;58:1111–4.
49. Komatsu R, Sengupta P, Wadhwa A, et al. Ultrasound quantification of anterior soft tissue thickness fails to predict difficult laryngoscopy in obese patients. Anaesth Intensive Care 2007; 35(1):32–7.
50. Murphy M, et al. Flexible fiberoptic intubation. In: Walls R, Murphy M, Luten R, et al, editors. Manual of emergency airway management. 2nd edition. Philadelphia: Lippincott Williams & Wilkins; 2004. p. 127–34.
51. Ezri T, Szmuk P, Warters R, et al. Difficult airway management practice patterns among anesthesiologists practicing in the United States: have we made any progress? J Clin Anesth 2003;15:418–22.
52. Marrel J, Blanc C, Frascarolo P, et al. Videolaryngoscopy improves intubation condition in morbidly obese patients. Eur J Anaesthesiol 2007;24(12): 1045–9.
53. Hirabayashi Y, Hakozaki T, Fujisawa K, et al. Use of a new video-laryngoscope (GlideScope) in patients with a difficult airway. Masui 2007;56(7):854–7.
54. Dhonneur G, Abdi W, Ndoko SK, et al. Video-assisted versus conventional tracheal intubation in morbidly obese patients. Obes Surg 2008, in press.
55. Reed A, Kramer D. Airway management. In: Alvarez A, Brodsky J, Alpert M, et al, editors. Morbid obesity: peri-operative management. Cambridge, UK: Cambridge University Press; 2005. p. 287–95.
56. Salem MR. Rapid sequence induction and intubation: fact and fiction. In: proceedings of the 2nd Annual Scientific Meeting of the Society for Airway Management. Newport Beach, California, September 5–7, 1997.
57. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia. Lancet 1961;2:404–6.
58. Vaughan RW, Bauer S, Wise L. Volume and pH of gastric juice in obese patients. Anesthesiology 1975;43:686–9.
59. Fisher BL, Pennathur A, Mutnick JL, et al. Obesity correlates with gastroesophageal reflux. Dig Dis Sci 1999;44(11):2290–4.
60. Zacchi P, Mearin F, Humbert P, et al. Effect of obesity on gastroesophageal resistance to flow in man. Dig Dis Sci 1991;36:1473–80.
61. Maddox A, Horowitz M, Wishart J, et al. Gastric and esophageal emptying in obesity. Scand J Gastroenterol 1989;24:593–8.
62. Hartsilver E, Vanner R, Bewley J, et al. Gastric pressure during emergency Caesarean section under general anaesthesia. Br J Anaesth 1999;82:752–4.
63. Harter RL, Kelly WB, Kramer MG, et al. A comparison of the volume and pH of gastric contents of obese and lean surgical patients. Anesth Analg 1998;86:147–52.
64. Kluger MT, Short TG. Aspiration during anaesthesia: a review of 133 cases from the Australian Anaesthetic Incident Monitoring Study (AIMS). Anaesthesia 1999;54(1):19–26.
65. Warner MA, Warner ME, Webber JG. Clinical significance of pulmonary aspiration during the perioperative period. Anesthesiology 1993;78:56–62.
66. Neilipovitz DT, Crosby ET. No evidence for decreased incidence of aspiration after rapid sequence induction. Can J Anaesth 2007;54: 748–64.
67. Garrard A, Campbell AE, Turley A, et al. The effect of mechanically induced cricoid force on lower oesophageal sphincter pressure in anesthetized patients. Anaesthesia 2004;59:435–9.
68. Smith KJ, Ladak S, Choi PTL, et al. The cricoid cartilage and the esophagus are not aligned in close to half of adult patients. Can J Anaesth 2002;49:503–7.
69. Smith KJ, Dobranowski J, Yip G, et al. Cricoid pressure displaces the esophagus: an observational study using magnetic resonance imaging. Anesthesiology 2003;99:60–4.
70. Saghaei M, Masoodifar M. The pressor response and airway effects of cricoid pressure during induction of general anesthesia. Anesth Analg 2001;93(3):787–90.
71. Freid E. The rapid sequence induction revisited: obesity and sleep apnea syndrome. Anesthesiol Clin North America 2005;23:551–64.
72. Haslam N, Parker L, Duggan JE. Effect of cricoid pressure on the view at laryngoscopy. Anaesthesia 2005;60(1):41–7.
73. Li J, Murphy-Lavoie H, Bugas C, et al. Complications of emergency intubation with and without paralysis. Am J Emerg Med 1999;17:141–3.
74. Bozeman WP, Kleiner DM, Huggett V. A comparison of rapid-sequence intubation and etomidate-only intubation in the prehospital air medical setting. Prehosp Emerg Care 2006;10:8–13.
75. Benumof JL. Laryngeal mask airway and the ASA difficult airway algorithm. Anesthesiology 1996;84: 686–99.
76. Frappier J, Guenoun T, Journois D, et al. Airway management using the intubating laryngeal mask airway for morbidly obese patients. Anesth Analg 2003;96:1510–5.

77. Combes X, Sauvat S, Leroux B, et al. Intubating laryngeal mask airway in morbidly obese and lean patients. Anesthesiology 2005;102:1106–9.
78. Banyai M, Falger S, Roggla M, et al. Emergency intubation with the Combitube in a grossly obese patient with bull neck. Resuscitation 1993;26: 271–6.
79. Della Puppa A, Pittoni G, Frass M. Tracheal esophageal Combitube: a useful airway for morbidly obese patients who cannot intubate or ventilate. Acta Anaesthesiol Scand 2002;46:911–3.
80. Urtabia R, Aguila C, Cumsille M. Combitube: a study for proper use. Anesth Analg 2000;90: 958–62.
81. Vezina D, Lessard M, Bussieres J, et al. Complications associated with the use of the esophageal tracheal Combitube. Can J Anaesth 1998;45: 823–4.
82. Matioc AA, Olson J. Use of the Laryngeal Tube™ in two unexpected difficult airway situations: lingual tonsillar hyperplasia and morbid obesity. Can J Anesth 2004;51:1018–21.
83. Agro F, Carassiti M, Magnani C, et al. Airway control via the CobraPLA during percutaneous dilatational tracheotomy in five patients. Can J Anaesth 2005;52:418–20.
84. Dimitriou V, Voyagis GS, Iatrou C, et al. The PAxpressTM is an effective ventilatory device but has an 18% failure rate for flexible lightwand-guided tracheal intubation in anesthetized paralyzed patients. Can J Anaesth 2003;50:495–500.
85. Frat JP, Gissot V, Ragot S, et al. for the Association des Réanimateurs du Centre-Ouest (ARCO) study group. Impact of obesity in mechanically ventilated patients: a prospective study. Intensive Care Med 2008;34(11):1991–8.
86. Engoren M. Evaluation of the cuff-leak test in a cardiac surgery population. Chest 1999;116: 1029–31.
87. Kriner EJ, Shafazand S, Colice GL. The endotracheal tube cuff-leak test as a predictor for postextubation stridor. Respir Care 2005;50(12):1617–8.
88. Ding LW, Wang HC, Wu HD, et al. Laryngeal ultrasound: a useful method in predicting post-extubation stridor. A pilot study. Eur Respir J 2006;27(2): 384–9.
89. Jiang JR, Tsai TH, Jerng JS, et al. Ultrasonographic evaluation of liver/spleen movements and extubation outcome. Chest 2004;126(1):179–85.
90. Benumof JL. Additional safety measures when changing endotracheal tubes. Anesthesiology 1991;75:921–2.
91. Loudermilk EP, Hartmannsgruber M, Stoltzfus DP, et al. A prospective study of the safety of tracheal extubation using a pediatric airway exchange catheter for patients with a known difficult airway. Chest 1997;111(6):1660–5.
92. Noninvasive positive pressure ventilation consensus statement: Consensus Conference on Noninvasive Positive Pressure Ventilation. Respir Care 1997;42:364–9.
93. Pauwels R, Buist AS, Calverley PMA, et al. Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2001;163:1256–76.
94. Shivaram U, Cash ME, Beal A. Nasal continuous positive airway pressure in decompensated hypercapnic respiratory failure as a complication of sleep apnea. Chest 1993;104:770–4.
95. Sturani C, Galavotti V, Scarduelli C, et al. Acute respiratory failure due to severe obstructive sleep apnoea syndrome, managed with nasal positive pressure ventilation. Monaldi Arch Chest Dis 1994;49:558–60.
96. Muir JF, Cuvelier A, Bota S, et al. Modalities of ventilation in obesity. Monaldi Arch Chest Dis 1998;53:560–3.
97. Duarte A, Justino E, Bigler T, et al. Outcomes of morbidly obese patients requiring mechanical ventilation for acute respiratory failure. Crit Care Med 2007;35:732–7.
98. Pankow W, Hijjeh N, Schuttler F, et al. Influence of noninvasive positive pressure ventilation on inspiratory muscle activity in obese subjects. Eur Respir J 1997;10:2847–52.
99. Rabec C, Merati M, Baudouin N, et al. Management of obesity and respiratory insufficiency: the value of dual-level pressure nasal ventilation. Rev Mal Respir 1998;15:269–78.
100. Pelosi P, Croci M, Ravagnan I, et al. Total respiratory system, lung, and chest wall mechanics in sedated paralyzed postoperative morbidly obese patients. Chest 1996;109:144–51.
101. Perez de Llano LA, Golpe R, Piquer MO, et al. Short and long term effects of nasal intermittent positive pressure ventilation in patients with obesity-hypoventilation syndrome. Chest 2005;128:587–94.
102. Taylor RR, Kelly TM, Elliott CG, et al. Hypoxemia after gastric bypass surgery for morbid obesity. Arch Surg 1985;120:1298–302.
103. El Solh A, Sikka P, Bozkanat E, et al. Morbid obesity in the medical ICU. Chest 2001;120:1989–97.
104. Gaszynski T, Gaszynski W, Strzelczyk J. Critical respiratory events in morbidly obese. Twoj Magazyn Medyczny Chirurgia 2003;3:55–8.
105. Blouw E, Rudolph A, Narr B, et al. The frequency of respiratory failure in patients with morbid obesity undergoing gastric bypass. AANA J 2003;71: 45–50.
106. Joris JL, Sottiaux TM, Chiche JD, et al. Effect of bi-level positive airway pressure (BiPAP) nasal ventilation on the postoperative pulmonary restrictive syndrome in obese patients undergoing gastroplasty. Chest 1997;111:665–70.

107. El Solh A, Aquilina A, Pineda L, et al. Noninvasive ventilation for prevention of post extubation respiratory failure in obese patients. Eur Respir J 2006;28: 588–95.
108. Astrachan DI, Kirchner JC, Goodwin WJ Jr. Prolonged intubation vs. tracheotomy: complications, practical and psychological considerations. Laryngoscope 1988;98:1165–9.
109. Diehl JL, El Atrous S, Touchard D, et al. Changes in the work of breathing induced by tracheotomy in ventilator-dependent patients. Am J Respir Crit Care Med 1999;159:383–8.
110. Rumbak M, Newton M, Truncale T, et al. A prospective, randomized study comparing early percutaneous dilational tracheostomy to prolonged translaryngeal intubation (delayed tracheotomy) in critically ill medical patients. Crit Care Med 2004; 32:1689–93.
111. El Solh A, Jaafar W. A comparative study of the complications of surgical tracheostomy in morbidly obese critically ill patients. Crit Care 2007;11:R3.
112. Thomas PS, Cowen ERT, Hulands G, et al. Respiratory function in the morbidly obese before and after weight loss. Thorax 1989;44:382–6.
113. Simmons B. Tracheotomy in sleep apnea syndrome. Ear Nose Throat J 1984;63:222–6.
114. Ghorayeb B. Tracheotomy in the morbidly obese patient. Arch Otolaryngol Head Neck Surg 1987; 113:556–8.
115. Tommerup B, Borgeskov S. Endoscopic evaluation at follow up after Bjork tracheostomy. Scand J Thorac Cardiovasc Surg 1983;17:181–4.
116. Gross ND, Cohen JI, Andersen PE, et al. 'Defatting' tracheotomy in morbidly obese patients. Laryngoscope 2002;112:1940–4.
117. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy. A new simple bedside procedure; preliminary report. Chest 1985;87:715–9.
118. Freeman BD, Isabella K, Cobb JP, et al. A prospective, randomized study comparing percutaneous with surgical tracheostomy in critically ill patients. Crit Care Med 2001;29:926–30.
119. Moe KS, Stoeckli SJ, Schmid S, et al. Percutaneous tracheostomy: a comprehensive evaluation. Ann Otol Rhinol Laryngol 1999;108:384–91.
120. Sustić A, Zupan Z, Antoncić I. Ultrasound-guided percutaneous dilatational tracheostomy with laryngeal mask airway control in a morbidly obese patient. J Clin Anesth. 2004;16(2):121–3.
121. Aldawood AS, Arabi YM, Haddad S. Safety of percutaneous tracheostomy in obese critically ill patients: a prospective cohort study. Anaesth Intensive Care 2008;36(1):69–73.
122. Heyrosa MG, Melniczek DM, Rovito P, et al. Percutaneous tracheostomy: a safe procedure in the morbidly obese. J Am Coll Surg 2006;202:618–22.
123. Byhahn C, Lischke V, Meininger D, et al. Peri-operative complications during percutaneous tracheostomy in obese patients. Anaesthesia 2005;60:12–5.
124. Mansharamani NG, Koziel H, Garland R, et al. Safety of bedside percutaneous dilatational tracheostomy in obese patients in the ICU. Chest 2000; 117:1426–9.
125. Scott MJ, Leigh J. Percutaneous tracheostomy in three morbidly obese patients using the "Blue Rhino technique." Anaesthesia 2000;55:917–9.
126. Unwin S, Short S, Hunt P. Percutaneous dilational tracheostomy in the morbidly obese. Anaesthesia 2000;55:393–4.
127. Kost KM. Endoscopic percutaneous dilatational tracheostomy: a prospective evaluation of 500 consecutive cases. Laryngoscope 2007;115:1–30.
128. Hatfield A, Bodenham A. Portable ultrasonic scanning of the anterior neck before percutaneous dilatational tracheostomy. Anaesthesia 1999;54:660–3.
129. Sustic A. Role of ultrasound in the airway management of critically ill patients. Crit Care Med 2007;35:S173–7.
130. Kollig E, Heydenreich U, Roetman B, et al. Ultrasound and bronchoscopic controlled percutaneous tracheostomy on trauma UCI. Injury 2000; 31:663–8.