Intensive care management of morbidly obese patients

Sunil Jamadarkhana MBBS MD FRCA EDIC
Abhiram Mallick MBBS MD FRCA FFARCSI FFICM
Andrew R Bodenham MBBS FRCA

Key points
The presence of an experienced intensivist with equipment for difficult intubation and skilled assistance is mandatory during airway interventions. During mechanical ventilation, current consensus favours ventilator settings based on ideal body weight followed by adjustments according to arterial blood gas measurements.

Considerable debate exists as to whether the use of total, ideal, or adjusted body weight is most appropriate for drug dosage calculations.

A hypocaloric feeding regime started within 24 h of admission achieves better nitrogen balance and prevents protein malnutrition. The use of ultrasound during vascular access procedures should be the routine standard of care.

Obesity is a growing epidemic in developed countries. There are an estimated 250 million obese people in the world. In the UK, nearly 25% of the adult population are obese according to data in 2006, and 66% of the population are overweight.1 In the USA, 66% of adults are overweight or obese and they represent more than 30% of intensive care unit (ICU) admissions.2 Obesity in critically ill patients is typically associated with increased morbidity and mortality, prolonged duration of mechanical ventilation (MV), and ICU length of stay.3

Obesity is defined as a BMI between 30 and 40 kg m⁻². A BMI between 40 and 50 kg m⁻² constitutes morbid obesity, and superobesity is a BMI >50 kg m⁻². A waist circumference of >102 cm in men and >88 cm in women indicates that there is a high risk of metabolic and cardiovascular complications.1 Altered physiology and pharmacokinetics, associated comorbidities (Table 1), and mechanical difficulties are specific issues to be considered in this group of patients. Healthcare professionals need to develop strategies for the efficient use of resources for this increasing patient population. Specific modifications are required for many aspects of ICU care in order to achieve good outcomes.

Typical reasons for ICU admission include:

(i) Elective or acute postoperative care (e.g. after bariatric, major abdominal, or vascular surgery).
(ii) Trauma: bone and soft tissue injury, or infection.
(iii) Treatment of a primary medical condition.
(iv) Complications due to co-morbid diseases.
(v) A relatively minor insult, for example, a chest infection or rib fractures, may cause acute respiratory decomposition in these patients.

Airway management
Tracheal intubation
Anatomical factors associated with a high probability of difficult intubation in these patients include: limited neck mobility and mouth opening, large breasts, short neck, large tongue, excessive palatal and pharyngeal soft tissue, high anterior larynx, short sternomental distance, receding mandible, prominent teeth, Mallampati score of 3 or more, and a large neck circumference. The presence of an experienced intensivist with advanced airway skills along with skilled assistance and equipment for difficult intubation is mandatory during any planned or unexpected airway interventions.

Diaphragmatic splinting due to excess abdominal fat causes decreased expiratory reserve volume and functional residual capacity (FRC). Decreased oxygen reserve and increased consumption leads to rapid desaturation despite pre-oxygenation before induction of anaesthesia or any loss of the airway or ventilation. The usual approach to intubation is to perform a rapid sequence induction (RSI) with cricoid pressure to prevent the reflux of gastric contents into the upper airway. Similar issues arise after planned or unplanned extubation.

The results of the Fourth National Audit Project (NAP4) in the UK concluded that the proportion of the obese population with airway complications was twice that of the general patient population. Airway obstruction during the use of supraglottic airway devices, aspiration of gastric contents during RSI, difficult intubation, displaced tracheostomy, and tracheal tubes were the most commonly observed complications. Rescue techniques were more likely to fail in this group of patients and failure to use capnography in ventilated patients contributed to more than 70% of ICU-related deaths.
Supraglottic airways

Various laryngeal mask airways (e.g. classical, intubating, and Proseal) and the Combitube have been used as rescue airway devices for failed intubation in morbidly obese patients. Although there is a risk of aspiration, the ability to ventilate and oxygenate is indispensable in an emergency scenario. These devices should be a mandatory component of the difficult airway trolley. There are a number of new supraglottic devices under development. However, there are limited data to show that any single device is better than another, particularly in the obese.

Tracheostomy procedures

Surgical tracheostomy has traditionally been considered the technique of choice in morbidly obese ICU patients. In these patients, standard tracheostomy tubes are generally too short due to the increased distance between the skin and the trachea. Tubes are more difficult to insert and also tend to become malpositioned or dislodged. Increasingly, custom-made tracheostomy tubes to fit the anatomy in obese patients are being used. Recent studies have shown that bedside percutaneous tracheostomy can be performed successfully in the morbidly obese using single-stage dilators and adjustable flange reinforced tracheostomy tubes (Fig. 1).

Emergency cricothyrotomy in a ‘cannot intubate, cannot ventilate’ scenario is also potentially more difficult due to increased neck circumference and thickness of subcutaneous tissues, which distorts anatomical landmarks. Cannula cricothyrotomy is considered preferable to needle cricothyrotomy in this group of patients, although evidence supporting one technique over another is limited. Standard positive pressure ventilation can be used with cannula cricothyrotomy, whereas jet ventilation is necessary with needle cricothyrotomy. Longer and larger (> 4 mm internal diameter) cuffed cricothyrotomy cannulas (Fig. 2) should be used and be a component of the difficult airway trolley. It is advisable to palpate, identify the landmarks, and mark the cricothyroid membrane in a morbidly obese patient before any airway instrumentation.

Mechanical ventilation

In the morbidly obese, the mechanics of the chest wall and lungs are altered compared with normal subjects due to:

(i) Encroachment of the large abdominal contents into the thorax and the weight of the chest wall and breasts restricting lung expansion.

(ii) Fat deposition in the diaphragm and intercostal muscles.

This reduces FRC, forced expiratory volume in 1 s, MV, and lung and chest wall compliance. All these coupled with high airway resistance due to reduced lung volume increases the work of breathing up to four-fold. This leads to ventilation–perfusion mismatch and dangerous levels of hypoxia. In a deteriorating obese patient, because of a very low respiratory reserve, early mechanical ventilatory support should be considered whenever possible.

Table 1 Co-existing medical problems of morbid obesity

<table>
<thead>
<tr>
<th>Condition</th>
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<tr>
<td>Type 2 diabetes mellitus</td>
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<td>Gallbladder disease</td>
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<td>Hyper tension</td>
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<tr>
<td>Hyperlipidaemia</td>
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<tr>
<td>Coronary artery disease</td>
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<tr>
<td>Restricted ventilation</td>
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<tr>
<td>Knee and hip osteoarthritis</td>
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<tr>
<td>Gout</td>
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<td>Cancer (breast, endometrial, and colon)</td>
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<td>Obstructive sleep apnoea (may be undiagnosed)</td>
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<tr>
<td>Soft tissue injury, infection, and low-back pain</td>
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<td>Frequent falls and trauma</td>
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Fig 1 Long stem adjustable flange tracheostomy tube (Portex, Hythe, Kent, UK) with detachable inner liner and percutaneous insertion kit.

Fig 2 Cannula cricothyrotomy set (Melker) consisting of a syringe, an introducer needle, guidewire, scalpel, and cannula (4 mm internal diameter) loaded over a dilator and tape.
 Controlled MV

During MV, current consensus favours parameters based on ideal body weight (IBW) initially and subsequently adjusting the ventilator settings according to regular arterial blood gas measurements. This is based on the expected decreased lung volumes and increased airway resistance. A tidal volume calculated according to total body weight (TBW) is likely to result in excessively high airway pressures, alveolar over-distension, and baro/atelectrauma.

Positioning the patient in a semi-erect posture at 45° will increase ventilation volumes by reducing the weight of the breasts and fat on the abdomen, chest wall, and diaphragm. High inflation pressures are likely to be required due to the reduced compliance of the total respiratory system. The literature suggests that limiting the transpulmonary pressure to about 35 cm H₂O is a reasonable approach. The addition of PEEP facilitates alveolar recruitment and prevents atelectasis. Suggested initial ventilator settings:

(i) high FiO₂ (60%);
(ii) tidal volume of 5–7 ml kg⁻¹ based on IBW;
(iii) PEEP of 7–10 cm H₂O;
(iv) peak inspiratory pressure of <35 cm H₂O.

Thereafter, adjust parameters according to the blood gases after lung recruitment manoeuvres.

Non-invasive ventilation

Bi-level positive airway pressure ventilation has been used after tracheal extubation after open gastric bypass surgery at a level of 12/4 cm H₂O (inspiratory/expiratory) to improve oxygenation. Nasal positive pressure ventilation appears to reduce the need for tracheal intubation and invasive MV in patients with obstructive sleep apnoea (OSA) or hypercapnic respiratory failure. The incidence of OSA has been reported to be as high as 40% and increases in proportion to BMI. OSA predisposes to hypoxaemia in the immediate post-extubation period, during which vigilant monitoring is required to prevent carbon dioxide narcosis. Routine preoperative screening for OSA is recommended before bariatric or other major surgery.

Vascular access and monitoring

Assessing and monitoring the circulation of a critically ill morbidly obese patient is another challenging task. It may be difficult to palpate the peripheral pulses and obtain arterial pressure using a standard cuff. Using an arterial pressure cuff with a width 40–50% of the upper arm’s circumference and an internal bladder length 80% of the arm’s circumference provides acceptable readings. An electrocardiogram may show low-voltage complexes due to the thick adipose tissue covering the chest wall. Obese patients have higher resting cardiac filling pressures which may further increase in the supine position. The use of cardiac filling pressures including central venous pressure and pulmonary capillary wedge pressure for fluid administration has low sensitivity and specificity in critically ill morbidly obese patients. Functional parameters including pulse pressure variation and stroke volume variation derived from arterial pressure waveform analysis using the LiDCO, the PiCCO, or measured by the oesophageal Doppler appear to be valuable guides for fluid administration.

Insertion of peripheral, central venous, and arterial catheters is often difficult due to altered anatomy. The depth and angle of needle insertion is increased. A femoral line may be particularly difficult due to impalpable landmarks, abdominal fat (pannus) overhanging the groin area, and high prevalence of fungal infections in this region. As a result of high central venous pressures, it is often possible to cannulate the internal jugular vein in the semi-upright position. The landmark technique for central venous access requires multiple needle passes and is associated with increased complication rates.

The use of ultrasound techniques to obtain internal jugular access increases successful catheter placement and reduces the risk of complications. It also decreases the need for multiple insertion attempts. Axillary or subclavian access is also possible with ultrasound, but vessels are deeper than usual. Ultrasound may also be helpful for arterial access.

Peripheral insertion of central catheters under ultrasound guidance is an alternative to centrally placed catheters.

Drugs

Enteral absorption of drugs is not altered in the morbidly obese. Several factors affect drug distribution, metabolism, and clearance in these patients, which include altered regional blood flow and volume of distribution, impaired metabolism, and renal clearance. As a result of the above changes, plasma levels of oral or parenteral drugs fluctuate on either side of their therapeutic range, often resulting in subtherapeutic rather than toxic levels. Therefore, monitoring of serum levels is considered more important in this group of patients. There is considerable debate as to whether the use of total, ideal, or adjusted body weight for calculation of drug dosages is appropriate. The following terms are described with regard to the weight of morbidly obese patients:

(i) actual or TBW;
(ii) IBW, based on Robinson’s formula:
(iii) for men IBW=51.65 kg + 0.74 kg cm⁻¹ of height >150 cm, for women IBW=48.67 kg + 0.66 kg cm⁻¹ of height >150 cm.
(iv) Adjusted body weight (ABW)=(TBW–IBW) 0.4 + IBW (calculated with 40% excess weight).

Recommendations for dosing of medications commonly used in the ICU are as shown in Table 2.

Opioids

Owing to considerable variation in analgesic requirements in patients with normal BMI and the morbidly obese, the use of a single calculation dose is not appropriate. The best approach for any patient requiring i.v. opioids is to use a series of smaller doses until the desired level of pain control is achieved. In patients requiring
**Table 2** Drug dosing regimens in critically ill morbidly obese patients.  

<table>
<thead>
<tr>
<th>Drug group</th>
<th>Dose modification required and body weight to be used</th>
<th>Sedatives (benzodiazepines, propofol)</th>
<th>Loading dose and continuous infusions based on IBW with subsequent titration based on clinical response</th>
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<tr>
<td>Neuromuscular blocking agents:</td>
<td>Non-depolarizing: loading dose and continuous infusions based on IBW with subsequent titration by clinical effect and peripheral nerve stimulation. Succinylcholine: based on TBW. Sugammadex: based on TBW.</td>
<td>Anticonvulsants</td>
<td>Phenytoin: loading dose: 14 mg kg⁻¹ IBW + 19 mg kg⁻¹ for the weight in excess of IBW up to a maximum of 2 g. Maintenance dose: IBW with subsequent titrations based on therapeutic drug monitoring and clinical effectiveness.</td>
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<tr>
<td>Anticoagulants</td>
<td>Unfractionated heparin: loading dose and initial maintenance infusions based on ABW with subsequent titration based on APTT (activated partial thromboplastin time) measurements. Low molecular weight heparin: based on ABW or dose capping strategy until results of anti-Xa monitoring obtained. For prophylaxis: higher end of suggested range.</td>
<td>Antibiotics</td>
<td>Aminoglycosides: ABW with a 12 h dosing interval and normal renal function. With once daily regime, maximum dose is 1 g day⁻¹. Therapeutic drug monitoring is required if given for 3–5 days. β-lactams: ABW, higher end of recommended treatment ranges. Quinolones: based on ABW. Vancomycin: based on TBW with more frequent doses.</td>
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<tr>
<td>Corticosteroids</td>
<td>Short course (&lt;2–3 days): based on ABW for dosing to avoid subtherapeutic levels of the drug and to limit side-effects. Long course: based on IBW.</td>
<td>Cardiac agents</td>
<td>Amiodarone, digoxin, procainamide, propranolol: based on IBW loading dose followed by supplemental doses. Lidocaine and verapamil: based on ABW for loading dose with supplemental doses, as needed based on clinical effect.</td>
</tr>
<tr>
<td>Histamine H₂ blockers</td>
<td>Based on ABW.</td>
<td>Histamine H₂ blockers</td>
<td>Based on IBW.</td>
</tr>
<tr>
<td>Theophylline</td>
<td>Based on IBW for both loading and maintenance doses with therapeutic drug monitoring</td>
<td>Theophylline</td>
<td>Based on IBW.</td>
</tr>
<tr>
<td>Vasoactive agents</td>
<td>Based on ABW.</td>
<td>Vasoactive agents</td>
<td>Based on ABW.</td>
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Continuous infusions, frequent pain assessments determine the need for more significant dose changes. Remifentanil may be preferred to fentanyl or alfentanil for sedation in this group of patients because of lack of accumulation and quick offset of action during wake up and extubation. The dose of remifentanil infusion should be calculated based on IBW rather than TBW and titrated to effect.⁸

**Venous thromboembolism prophylaxis**

Obesity is an independent risk factor for the development of venous thromboembolism (VTE). It has been implicated as the most common cause of postoperative mortality after bariatric surgery resulting in up to 50% of all deaths. Primary prevention is the key to reduce morbidity and mortality from VTE in the critically ill morbidly obese. Only a few medications used for VTE prophylaxis have been specifically studied in obese patients. The suggested doses of low molecular weight heparins for VTE prevention have been extrapolated from studies involving patients with a range of weights. However, clinical efficacy has not been tested except in limited trials of patients undergoing bariatric surgery. In a recent study, it has been shown that the use of weight-based enoxaparin dosed at 0.5 mg kg⁻¹ once daily is feasible and results in anti-Xa levels within the recommended range for thromboprophylaxis, without any evidence of excessive anti-Xa activity. These data suggest that a weight-based regimen using TBW may be more effective than a standard fixed-dose regimen.⁹

**Nutrition**

Critically ill morbidly obese patients are prone to develop protein malnutrition as a result of metabolic stress, despite having excess body fat stores. The elevated basal insulin level in obesity suppresses lipid mobilization from body stores, causing an accelerated breakdown of protein to glucose. Excess protein breakdown results in a rapid decrease in lean body mass and an increased production of urea, leading to protein energy malnutrition. Nutrition should therefore be started as soon as feasible after stabilization, preferably within 24 h and via the enteral route. In morbidly obese patients, indirect calorimetry is considered the method of choice to determine energy expenditure if the inspired oxygen is <60% but is not widely used. If indirect calorimetry is not available, the current consensus favours nutritional support of 20–30 kcal kg⁻¹ day⁻¹ on the basis of obesity-adjusted weight [IBW + (ABW–IBW) x 0.25]. The protein requirements in this group of patients are difficult to determine and current evidence suggests 1.5–2.0 g kg⁻¹ of IBW per day.⁶

Most of the calories should be given as carbohydrates and fat to prevent fatty acid deficiency. A hypocaloric enteral feeding regimen achieves proper nitrogen balance compared with a eucaloric regimen. In a retrospective study of 40 critically ill obese surgical patients, the hypocaloric-feeding group had significantly shorter ICU stays, fewer days of antibiotic therapy, and a trend towards a decrease in the days of MV.¹⁰

Enteral feeding is the preferred mode of nutrition. Radiographic verification of nasogastric tube placement may pose a practical challenge secondary to the patient’s large size. Filling the lumen of the nasogastric tube with contrast before chest X-ray is helpful. Hypocaloric parenteral nutrition should be considered if patients cannot be fed by the enteral route at the outset or develop persistent intolerance to enteral feeding.¹⁰

**Skin and soft tissue infection**

Morbidly obese patients are more susceptible to skin breakdown and impaired wound healing due to excess subcutaneous fat and associated comorbidities. Hypotension and hypoxia during the critically ill phase results in decreased tissue perfusion which compromises
skin integrity. Other factors that influence skin breakdown are sedation, use of neuromuscular blocking agents, fluid overload, fever, incontinence, difficulties in moving and handling, and mechanical trauma. These need to be continually assessed in the obese critical care patient. The risk of pressure ulcer development is 1.5–3 times higher in the morbidly obese compared with patients of normal BMI.¹¹

Common skin conditions seen in these patients are diabetic foot ulcers, venous insufficiency ulcers, lymphoedema, intertrigo, psoriasis, perineal dermatitis, and pressure ulcers. Infections, wound dehiscence, graft failure, and seroma formation are common surgical wound complications. Skin and wound conditions commonly develop over the abdominal area due to a large abdominal apron or panniculus. Panniculectomy surgery is performed to remove the massive pannus. Occasionally, cellulitis develops over the panniculus either due to infection, injury, or abdominal surgery. This is treated by a wide en bloc excision of skin, subcutaneous tissue, muscle, and strangulated intestine, which facilitates successful fascial and skin closure in the non-infected field.¹¹

**Nursing care**

Critically ill obese patients are best nursed in a 45° upright position on the ICU. Bariatric beds with low air-loss surfaces or air-fluidized beds with pressure relief features may help in preventing pressure ulcers. Fungal infections are very common in the intertriginous areas, which should be treated with antifungal powders or creams. Placement of a soft folded cloth between the surfaces of skin folds reduces friction and absorbs moisture. If a patient is incontinent, urine and faecal catheters along with appropriate sized incontinence briefs or pads are required to absorb moisture and maintain skin integrity.¹¹

**Equipment, physiotherapy, and mobilization**

When caring for the morbidly obese patient on the ICU, it is important to know the weight limits of all lifting or support equipment. Staff looking after morbidly obese patients must be trained in moving and handling to reduce injury and promote patient safety. Basic equipment necessary for the care of these patients include large beds with strong side railings, large pressure-relieving mattress, hoist, kinetic bed, and large chairs. The weight of additional equipment such as i.v. pumps, monitors, and oxygen cylinders should also be taken into consideration. Transfer equipment and beds need to be appropriately sized, and have adequate weight limits. Beds that are wide enough to adequately turn the patient side to side are necessary to prevent skin breakdown. Overhead ceiling lifts or freestanding lifts help in easy mobilization. Prolonged immobility on the ICU leads to difficulty in weaning as a result of atelectasis and pneumonia. Weaning from MV is facilitated by mobilizing the patient. Aggressive physiotherapy with incentive spirometry and safe mobilization of morbidly obese patients helps facilitate early recovery and discharge from the ICU. Utilizing appropriate equipment and interdisciplinary protocols help in achieving a better outcome.

**Intra- and inter-hospital transfer**

Critically ill morbidly obese patients may require transfer from the ICU to another hospital or internally to the operating theatre or radiology department. These patients are better transferred on their own purpose-built beds rather than trolleys. The weight limitations of the scanner or operating table need to be ascertained to avoid a futile transfer. Veterinary scanners with a large ‘donut’ can be used for these patients, but this typically requires off-site transfer. ICU staff need to be trained in moving and handling of these patients and an adequate number should accompany the patient to ensure a safe transfer. The thick chest wall decreases the quality of portable chest X-rays and ultrasound images. Better images are obtained from a CT scan. Magnetic resonance venography should be considered for investigation of any intrapelvic and proximal vein thrombosis.

Interhospital transfer by road or air carries many practical difficulties, which include the requirement and availability of large ambulances to accommodate the patient and transferring personnel, weight and width limitations of the stretchers, and instability during transfer. Large modified stretchers with several handles and no weight restrictions are available. During aeromedical transfers, pneumatic or hydraulic lifts are required to lift the stretchers to cabin height.

**Outcomes after ICU care**

Morbid obesity results in several complications and may be associated with potentially worse outcomes during ICU stay. Prognostic indicators used in ICUs such as APACHE (Acute Physiologic and Chronic Health Evaluation) II and III and SAPS (Simplified Acute Physiological Score) II and III do not take a patient’s BMI into consideration. Thus, obesity is not captured by these prognostic indicators. A number of studies have looked into ICU and hospital mortality with conflicting results as to whether obesity increases the risk of death in critically ill patients.²,¹² Two recent meta-analyses demonstrated no difference in mortality between critically ill obese patients and those with normal BMI.¹³,¹⁴ The results of these studies have shown a trend towards improved outcomes in obese and overweight patients compared with those with normal BMI. This phenomenon has been called the ‘obesity survival paradox’ and has also been demonstrated in a recent study of mechanically ventilated surgical ICU patients, where overweight or obese patients showed a decreased risk of 60 day in-hospital mortality.¹⁵

**Conclusions**

Care of the morbidly obese patient on the ICU presents a formidable challenge to healthcare professionals and has considerable economic implications. With adequate training of staff and appropriate use of
resources along with multidisciplinary team management including relatives of patients, better outcomes can be achieved.

**Declaration of interest**

None declared.

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