7.17 Trauma and critical care

7.17.1 Critical care

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Key points

- Up to 75% of patients survive an intensive care unit (ICU) admission; however, many are left with severe weakness and delayed recovery.
- The critical illness, ICU procedures, equipment and medications all influence nutritional provision and need to be accounted for.
- Enteral feeding is the route of choice, and feeding should commence within 48 hours of admission; the accurate assessment of energy and protein requirements remains controversial.
- An individualised approach to nutrition support is advocated that adjusts to the different phases of critical illness.

Approximately half of all prescribed feed is delivered to patients while in an ICU; however, strategies need to be employed to optimise nutrition delivery. ICUs are modern high-tech units with a vast array of equipment designed to support each of the body systems. The ICU multidisciplinary team (MDT) includes intensivists, medical and nursing staff, pharmacists, dietitians and physiotherapists, as well as access to speech and language therapy, occupational therapy and psychology. There are nationally recognised recommendations for the role of the critical care dietitian and clinical standards for dietetic provision (Masterson & Baudouin, 2015). The critical care dietitian should:

- Lead the development and implementation of nutrition-related protocols and guidelines in association with the MDT.
- Consider nutrition risk, when planning patient-specific nutritional interventions such as parenteral nutrition (PN).
- Lead nutrition-related audit and research to widen the evidence base and to evaluate nutrition-related research.
- Contribute to consultant-led ward rounds and MDT meetings, and have regular consultant communication where nutritional goals and plans are discussed as per the NICE guideline CG83 (NICE, 2009).
- Provide ongoing education and training for clinicians, nurses and allied health professionals (AHPs), and act as a resource for other professionals.
- Contribute to appropriate strategic meetings and clinical governance activities.

Diagnostic criteria and classification

Approximately 249,000 patients a year require admission to English ICUs, and this is increasing annually (NHS, 2015). Patients are classified according to the severity of the illness and the level of support that is needed, rather than their hospital location, e.g. ICU or high-dependency unit (HDU) (Table 7.17.1).

Metabolic response to injury, trauma and sepsis

The changes that occur following stress (injury, trauma or sepsis) are different to those from starvation, as they aim to mobilise tissues for defence and repair in an attempt to survive. Cuthbertson *et al.*'s (2001) pioneering work introduced the terms ebb and flow to describe the metabolic response. The response is complex and involves interactions and physiological responses, including counter-regulatory hormones and cytokines. It is now believed that nutrition support should be individualised to the metabolic demand over the different phases of

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Table 7.17.1 Classification of patients in the acute hospital setting

Classification	Level of support required
Level 0	Patients whose needs can be met through normal ward care in an acute hospital.
Level 1	Patients at risk of their condition deteriorating, or those recently relocated from higher levels of care, whose needs can be met on an acute ward with additional advice and support from the critical care team.
Level 2	Patients requiring more detailed observation or intervention, including support for a single failed organ system or postoperative care, and those stepping down from higher levels of care.
Level 3	Patients requiring advanced respiratory support alone or basic respiratory support, together with support of at least two organ systems.

critical illness, i.e. limiting energy in the early phase and increasing slowly during stabilisation and rehabilitation (McClave *et al.*, 2016; Preiser *et al.*, 2015; Singer *et al.*, 2014).

Ebb phase

This occurs immediately after the injury and lasts approximately 24–48 hours. There is a reduction in metabolic activity and oxygen consumption, and a fall in body temperature. Energy reserves, e.g. glucose from liver glycogen and free fatty acids from adipose tissue, are mobilised, but there is impairment in the ability to use them.

Flow phase

The second phase is called the flow or acute phase, and it is mediated by cytokines, hormones and changes in nutrient metabolism. The length of the flow phase depends on the severity of the injury and the resolution of the traumatic or septic insult. After uncomplicated major surgery, the patient can be expected to enter the anabolic phase within 2–3 weeks, but, with major burns or unresolved sepsis, the breakdown of lean tissue continues for as long as the pathological stimulus is present.

Counter-regulatory hormones

The levels of these hormones (catecholamines, glucagon and cortisol) increase, resulting in increased protein mobilisation and subsequent catabolism. They are responsible for the hyperglycaemia and insulin resistance commonly seen in critically ill patients. Glucagon stimulates gluconeogenesis, cortisol increases net protein catabolism, and the catecholamines lead to glucose intolerance.

Cytokines

Circulating levels of pro-inflammatory and anti-inflammatory cytokines also increase. Interleukin (IL)-1, IL-6 and tumour necrosis factor alpha (TNFα) are the major proinflammatory mediators. They act in conjunction with the various hormones on hepatic and peripheral tissue to increase lean tissue breakdown and loss.

Gluconeogenesis and protein metabolism

Following injury, glucose is an important fuel for the central nervous system, wounds and the immune system, all of which are metabolically active during stress. Glycogen stores are quickly depleted, so the need for available glucose is met from muscle protein breakdown for hepatic gluconeogenesis. Amino acids derived from muscle breakdown are also required for the synthesis of the acute-phase proteins, e.g. C-reactive protein (CRP). During the flow phase, achievement of energy balance, which fails to alleviate catabolism in critically ill patients, is the most that can be hoped for, to attenuate the rate of loss.

Anabolic phase

Eventually, catabolism declines, and the flow phase passes into the anabolic or recovery phase. Metabolic rate decreases, and fluid status and insulin sensitivity return to pre-injury levels, which are usually coupled with an increase in appetite and ambulation. Nutritional therapy should now aim to increase protein synthesis and restore muscle mass.

Disease consequences

Although 75% of patients return home after an ICU stay (NICE, 2009), many are left with delayed recovery, e.g. loss of muscle mass, severe weakness, impaired exercise capacity and fatigue; commonly termed ICU-acquired weakness (ICUAW), which is associated with a longer hospital stay, reduced likelihood to return home after hospital discharge, and reduced long-term survival (Arabi *et al.*, 2017). ICUAW was initially described in patients following acute respiratory distress syndrome (ARDS) (Herridge *et al.*, 2003), but is now considered to affect all patients (Herridge *et al.*, 2016). It is attributed to a combination of the following risk factors (Kress & Hall, 2014):

- Prolonged, controlled mechanical ventilation.
- Persistent systemic inflammation.
- Multi-organ failure.
- Immobilisation.
- Hyperglycaemia.
- Steroids.
- Paralysing agents.

For many ICU survivors, exercise limitations and disability persist at 5 years, and is associated with increased healthcare costs (Herridge *et al.*, 2016); one-third of patients never work again (Herridge *et al.*, 2016). This is not surprising as ICU patients can lose up to 2% of their muscle mass a day (Griffiths & Jones, 1999). Patients can be so weak on discharge to a ward that they are unable to feed themselves. Impaired coughing and swallowing can place them at risk of aspiration, and taste changes can further compromise nutritional status. Poor

recovery post-ICU is a major public health issue and the subject of guidelines (NICE, 2009).

Nutritional consequences

Dietitians working in critical care should familiarise themselves with the equipment, procedures, disease process and medications used, to ensure that nutritional assessments and diet therapy are safe and appropriate. Tables 7.17.2 and 7.17.3 give details of the equipment and medications commonly used in the ICU and their nutritional implications. Table 7.17.4 highlights the factors that can increase and decrease energy expenditure.

Nutritional assessment

Anthropometry

Many patients are admitted to the ICU as emergency cases, intubated and sedated, and therefore cannot give their weight or height. Patients are bedbound, and obtaining an accurate weight and height is challenging. Some ICU beds weigh patients, but weights obtained may reflect fluid status and include bed equipment. Oedema and fluid retention can cause weight to increase by 10–20% in a single day (Lowell *et al.*, 1990), thus making anthropometric measures commonly used elsewhere inaccurate. Surrogate measures for height can be used, although these have not been validated for use within the ICU.

Biochemistry

Assessment of biochemistry is carried out frequently, often twice a day, plus blood gas measurements. Many factors during critical illness, e.g. gut losses, diuresis, volume expansion and internal redistribution, and renal replacement therapy alter biochemical values. Low electrolyte levels are not always related to nutritional status or refeeding syndrome. It is common practice to aim for upper limits of potassium, magnesium and phosphate due to their therapeutic properties. Twenty four hours is a long time in the ICU, and blood results from a previous day may be of little help in assessing the current picture. Fluid balance can be radically altered by critical illness owing to the metabolic response to stress, inflammation, malnutrition, drug treatment and organ dysfunction. Assessing fluid needs is complex and difficult to perform. It is best for the ICU medical team to lead the management of fluid requirements, and requires close collaboration within the team, which includes a dietitian (see Chapter 6.6, Parenteral nutrition).

Clinical and nutritional assessment

Identifying which patients are at nutritional risk is a key skill of the critical care dietitian. The process should detect those patients at high risk and most likely to benefit from nutrition support. In a large study where nutritional status was assessed by a dietitian, 55% were shown to be malnourished on admission to the ICU, and this was a significant predictor of 30-day mortality

Table 7.17.2 Commonly used equipment in the intensive care unit (ICU) and their nutritional implications

Equipment	Purpose	Nutritional considerations
Mechanical ventilator	Controls breathing pattern. Different settings to suit patient's needs, e.g. mandatory ventilation (machine doing all the breathing) and spontaneous ventilation (the patient initiates the breaths).	The different settings can either reduce (mandatory ventilation) or increase (spontaneous ventilation) the work of breathing, which influences energy expenditure and energy requirements (Hoher *et al.*, 2008).
Endotracheal tubes (ETT)	Tubes used to provide mechanical ventilation. The ETT is passed through the mouth or nose into the trachea. Used for short-term ventilation.	The tube makes it difficult to coordinate swallowing. Oral intake is usually avoided. Can cause temporary dysphagia when removed.
Tracheostomy	Tracheostomy is inserted into the trachea via the neck. Used for mid- to long-term ventilation.	Swallowing difficulties as listed in the preceding text. In special circumstances, oral trials can be facilitated, usually with the help of an experienced speech and language therapist.
Airflow cooling blanket	Used to decrease body temperature. Aims to achieve body temperature of 35 °C. Used as a treatment following cardiac surgery and after cardiac arrest.	Significantly lowers energy expenditure and energy requirements. Use a predictive equation that takes temperature into consideration (Faisy *et al.*, 2003; Frankenfield *et al.*, 2004).
Continuous renal replacement therapy	Used to treat acute kidney injury in ICU patients. Clears unwanted solutes and large volumes of fluid.	Loss of electrolytes, e.g. phosphate and magnesium. Loss of 5–10 g of protein/day, dependent on modality type. Loss of water-soluble vitamins. Loss of trace elements, e.g. selenium (Cano *et al.*, 2009).

Table 7.17.3 Drug–nutrient interactions

Drug	Nutritional consideration
Opioid analgesia/sedation agents, e.g. fentanyl and morphine	Can cause constipation and decrease gut motility, resulting in reduced gastric emptying.
Propofol	1 kcal/mL – contributes additional energy. Only take into consideration if taken over a prolonged period. Risk of fat overload.
Paralysing agents, e.g. atracurium and pancuronium	Decrease energy expenditure and gut motility.
Phenytoin, rifampicin, ciprofloxacin, raltegravir or penicillin V	If given via the enteral route, require a break from feed to allow drug absorption.
Intravenous fluids, e.g. crystalloids and colloids	Can contribute to sodium overload.
Inotropes and vasopressors, e.g. noradrenaline (norepinephrine), adrenaline (epinephrine), dobutamine and vasopressin	High doses cause a reduction of hepatic, renal and splanchnic blood flow. Can lead to risk of gut ischaemia.
Regional citrate anticoagulation	Infused during continuous renal replacement therapy, can contribute considerable energy intake which should be monitored.
Prokinetics, e.g. metoclopramide and erythromycin	Enhance gut motility and help overcome delayed gastric emptying. Assist in Nasojejunal tube placement.
Sliding-scale insulin therapy	Hypoglycaemia risk with interruptions to feeding.
Stress ulcer prophylaxis, e.g. lansoprazole, esomeprazole, omeprazole and ranitidine	Alters pH and can make nasogastric tube placement confirmation by pH paper unreliable.
Furosemide (loop diuretic)	Increases excretion of potassium, magnesium, sodium, calcium. May need supplementation.
Corticosteroids	Increases glucose levels. Increases sodium and water retention and potassium and calcium excretion.

Table 7.17.4 Factors commonly associated with either an increase or decrease in energy expenditure in hospitalised patients

Factors increasing energy expenditure	Factors reducing energy expenditure
Pyrexia	Sedation, anaesthesia
Disease state – the sicker the patient, the higher the energy expenditure	Age
Surgery	Neuromuscular blocking agents (paralysis), barbiturates, coma
Recovery phase of critical illness	Acute phase of critical illness
Abnormal losses, e.g. wound exudate, diarrhoea and vomiting	Starvation
Infection, chest infection and shivering	Reduced mobility / immobility
Pain	Hypothermia / active cooling
Extraneous movements, e.g. following head injury	
Exercise and rehabilitation	
Dressing changes	

(Mogensen *et al.*, 2015). Several clinical factors will affect the loss of muscle mass, including pre-existing malnutrition, sarcopenia, severity of illness, intensity of the inflammatory response and adequacy of nutrition support provided (Heyland *et al.*, 2011). Due to poor outcomes associated with malnutrition and ICUAW, there is interest in how best to assess nutritional risk. McClave *et al.* (2016) recommend that nutritional risk be assessed for all patients admitted to ICU for whom volitional intake is anticipated to be insufficient. The use of the nutrition risk score (NRS) (Kondrup *et al.*, 2003) or the nutrition risk in critically ill (NUTRIC) score (Heyland *et al.*, 2011) are advocated. The NUTRIC score places emphasis on severity of illness and inflammation in identifying disease-related nutritional risk; it does not include any direct measure of nutritional status. Patients are categorised as high or low risk. A positive association has been shown between nutritional adequacy and 28-day survival in patients with a high score, but this association diminishes with decreasing NUTRIC score (Rahman *et al.*, 2016). The NRS places all ICU patients at high risk due to illness score, and therefore is not very meaningful.

New measures such as ultrasound measurements (Puthucheary *et al.*, 2013) and CT scans (Paris & Mourtzakis, 2016) of muscle mass are described as tools to incorporate into nutritional assessments. There is still

more to be done on standardising techniques and ensuring reproducibility and accurate interpretation before they are ready for use in clinical practice (Connolly *et al.*, 2015). At present, it is unknown if muscle mass is influenced by nutritional intake, or if it indicates disease severity (Arabi *et al.*, 2017).

Nutritional management

Timing of initiation of nutrition support

Early nutritional support is commonly defined as commencing 24–48 hours after admission and is routinely recommended in international guidelines (Critical Care Nutrition, 2015; McClave *et al.*, 2016). Early enteral nutrition (EN) can maintain gut integrity, modulate stress and the systemic immune response, attenuate disease severity and reduce mortality and infections (McClave *et al.*, 2016).

Route of nutrient delivery

EN is considered to be the first choice of nutrition support (Critical Care Nutrition, 2015; Kreymann *et al.*, 2006; McClave *et al.*, 2016); however, the delivery is frequently disrupted due to gastrointestinal (GI) intolerance (Wang *et al.*, 2016) or fasting for diagnostic procedures, surgery and airway management, resulting in poor nutrition support delivery (Segaran *et al.*, 2015). Cumulative energy deficits contribute to malnutrition, increased infections, increased ICU and hospital stay and mortality (Elke *et al.*, 2014; Singer *et al.*, 2010). In a recent systematic review, the use of EN was compared with PN, there was no effect on overall mortality, but decreased infectious complications and ICU length of stay (LOS) (Elke *et al.*, 2016). However, differences in the caloric intake between the subgroups may influence the observed effects (Elke *et al.*, 2016).

Historically, there have been important differences between the European and American societies' recommendations for the use of PN in critically ill patients. The European Society for Parenteral and Enteral Nutrition (ESPEN) guidelines (Singer *et al.*, 2009) advocate early use of PN if nutritional needs are not met in 2 days. In contrast, the American perspective is to withhold PN for the first 7 days (McClave *et al.*, 2016). For many decades, PN has been associated with increased infections (Simpson & Doig, 2005); however, the CALORIES trial (Harvey *et al.*, 2014) challenged this perception. In this large study, patients were randomised for receiving EN or PN within 36 hours of ICU admission for the first 5 days. It demonstrated no difference between the patients in terms of 30-day mortality or infectious complications. It should be noted that the targets of 25 kcal/kg/day were not achieved in either the EN or PN group. This study confirms that PN is not harmful in critically ill patients who are fed less than 25 kcal/kg per day. Although the CALORIES trial provides valuable information regarding the optimal route of nutrition support, it does not define the optimal dose or timing of PN.

Two landmark trials have attempted to address the timing of supplemental PN, with conflicting results (Casaer *et al.*, 2011; Heidegger *et al.*, 2013). The EPaN-IC trial compared the impact of early (day 2) PN with late initiation (day 8) to supplement inadequate EN. An increase in infectious episodes and days of mechanical ventilation were reported with early supplemental PN; no differences in 90-day mortality were observed (Casaer *et al.*, 2011). Although this is a large, well-conducted study, the results need to be interpreted with caution, primarily due to the lack of generalisability, as 60% of the patients studied had undergone cardiac surgery. Additionally, they were not malnourished, and less than 50% were still in ICU after day 3. Typically, these are patients who were of low nutritional risk, who would not normally receive nutrition support. Those in the early supplemental PN group received high energy targets. The overfeeding seen in this trial in patients with low nutritional risk may explain the increase in infections and mechanical ventilator days.

Heidegger *et al.* (2013) studied patients receiving EN who did not reach 60% of energy requirements as measured by indirect calorimetry (IC) by day 3. The patients were randomised to receive EN or both EN and supplementary PN from days 4 to 8. A reduction in infections and less days on antibiotics was observed in patients receiving supplementary PN. Doig *et al.* (2013) considered only those patients with relative contraindications to EN and randomised them to receive either standard care or early PN starting on day 1. Early PN resulted in significantly fewer days of mechanical ventilation but no difference in 60-day mortality and infections. In summary, the CALORIES trial (Harvey *et al.*, 2014) identified that PN is not more harmful than EN when excessive energy is avoided. EN remains the first choice; however, if EN fails, either exclusive or supplementary PN should be considered in appropriate patients, i.e. those who are at nutritional risk or malnourished.

What targets should we aim for – hypocaloric feeding or full-energy feeding?

The optimal dose of nutrition support is still unknown. Some advocate full-calorie feeding, and others suggest the use of hypocaloric nutrition, making it confusing to know what to aim for. To add to the confusion, there is no standard definition for terms such as permissive underfeeding, trophic feeding and hypocaloric feeding. All advocate a reduction in energy, but the targets are often different, i.e. 10–20 mL/hour, or 500–1000 kcal/day, or 10 kcal/kg. The arguments for achieving full-energy feeding originate from large observational studies, e.g. Heyland *et al.* (2011) showed that patients who received more than two-thirds of their energy target were much less likely to die as compared to those receiving suboptimal energy. In an earlier study, an increase of 1000 kcal/day was associated with a decrease in mortality and days on ventilation in patients with a BMI of <25 kg/m^2 and >35 kg/m^2, with no benefit in those in the BMI range of 25–35 kg/m^2 (Alberda *et al.*, 2009). When the NUTRIC

score was used to categorise nutrition risk, those with high scores appeared to benefit most from aggressive nutrition support. However hypocaloric nutrition may not be harmful in those with low nutritional risk (Heyland *et al.*, 2011).

Interest in hypocaloric feeding has increased recently following the EDEN trial (Rice *et al.*, 2012) and the PERMIT trial (Arabi *et al.*, 2015). The EDEN trial was a multicentre randomised controlled trial (RCT) of initial trophic compared with full enteral feeding for up to 6 days in patients with ARDS; it found no significant differences in mortality and days without ventilation. The PERMIT trial randomised patients to permissive underfeeding or standard enteral feeding while maintaining a similar protein intake in both groups. This trial also found no differences in mortality, infections or LOS. A post-hoc analysis identified no differences in outcomes between high and low NUTRIC scores when comparing permissive and standard feeding practices (Arabi *et al.*, 2017), although there are limitations in using the NUTRIC score, as discussed earlier. The meta-analysis from Marik and Hooper (2016) found no differences in the risk of infections, mortality, ICU LOS and mechanical ventilation days, when comparing hypocaloric feeding with standard feeding. Al-Dorzi *et al.* (2016) also undertook a systematic review and meta-analysis of 21 studies, although 15 of these did not set out to measure hypocaloric feeding versus standard feeding. No association was found between the energy dose and hospital mortality. Lower energy intake was associated with lower risk of blood stream infections and renal replacement therapy. This may suggest that hypocaloric feeding is as good as full-energy feeding for some critically ill patients, but is not generalisable for all. Most patients were studied in the early acute phase, and were relatively young and well-nourished. For most of the studies, the energy and protein intake did not reach the recommended amounts for either group, so in fact they are comparing two different forms of underfeeding. The included studies only considered ICU outcomes, and this might be too early to see a benefit from nutrition support or detrimental effects from underfeeding. Long-term follow-up of patients enrolled in the EDEN study shows potential benefits in physical recovery in the full-fed group as compared to the hypocalorically fed group (Needham *et al.*, 2013). The exact amount of energy needed remains unknown. More large-scale RCTs are needed in a range of ICU patients over longer time periods. Optimal might be 70–80% of target requirements; however, due to frequent under-delivery, full-target EN should be the aim (Critical Care Nutrition, 2015; McClave *et al.*, 2016; Zusman *et al.*, 2016).

Overfeeding

Overfeeding macronutrients to critically ill patients can negatively affect organ function, particularly the lungs, liver and kidneys. Any excessive intake, but particularly excessive carbohydrate, can result in hypercapnia (carbon dioxide retention), which potentially prolongs the need for mechanical ventilation (Liposky & Nelson, 1994). Additionally, overfeeding carbohydrate can lead to hyperglycaemia, hypertriglyceridaemia and fat accumulation in the liver. Overfeeding protein can lead to azotaemia, uraemia, hypertonic dehydration and metabolic acidosis if the kidneys are unable to sufficiently adjust urea excretion or acid–base balance. Excessive fat infusions from PN can result in hypertriglyceridaemia and fat overload (Klein *et al.*, 1998). Non-nutrition energy sources can make a significant energy contribution and lead to overfeeding if not taken into consideration. The anaesthetic propofol is administered as a high-lipid infusion (Intralipid), and contributes 1 kcal/mL of additional energy. It can cause hypertriglyceridaemia when used in excessive doses. Additionally, intravenous dextrose and regional citrate anticoagulation, used during continuous renal replacement therapy, can contribute considerable calories and require monitoring to prevent overfeeding from occurring. Intravenous dextrose can contribute considerable energy. The underweight, overweight and elderly are particularly vulnerable to overfeeding, because of the difficulties in assessing their true requirements.

Prediction of energy targets

One of the biggest challenges is the assessment of metabolic rate for critically ill patients. The most accurate method is IC, although few dietitians have access to the equipment. Therefore, standardised equations are used to estimate metabolic rate. Many equations are available, but data are sparse on how they compare against measured energy expenditure (MEE) in a range of patients, e.g. the elderly, malnourished and obese. The energy expenditure (EE) of critically ill patients is variable; it increases and decreases over the different ICU phases, making the prediction of requirements challenging. It is influenced by the impact of critical illness and its many treatments (see Table 7.17.4).

There are a number of critical illness predictive equations such as Swinamer *et al.* (1990), Ireton-Jones *et al.* (1992), Penn State (Frankenfield *et al.*, 2004) and Faisy *et al.* (2003). Except for the Ireton-Jones equation, the others incorporate physiological factors such as temperature and ventilation settings, making them more applicable. The Penn State equation is considered the most accurate when compared to MEE (Frankenfield *et al.*, 2009), and is used by many ICU dietitians. However, there is general agreement that predictive equations are not sufficiently accurate for reliable use in critically ill patients (Fraipont & Preiser, 2013). Significant discrepancies exist between the predicted equations and IC (Tatucu-Babet *et al.*, 2016). For these reasons, international guidance suggests that, in the absence of IC, the targets should be 20–25 kcal/kg in the early phase and 25–30 kcal/kg once stable. For those in the active rehabilitation phase, needs could exceed 30 kcal/kg. Estimated EE should be re-evaluated at least once a week, adjusting to the different stages of critical illness (McClave *et al.*, 2016; Preiser *et al.*, 2015; Singer *et al.*, 2014).

Estimation of protein targets

Optimal protein targets are a challenge to determine during critical illness. The nitrogen balance obtained from 24-hour urine collections does not reflect whole-body protein balance. Protein is synthesised and lost via the liver, gut and immune system, and estimations of these losses are needed. Optimal protein provision matched to the phase of critical illness is thought to influence outcomes of critically ill patients, such as survival, reducing loss of lean body mass (LBM) and maintaining functional outcomes after a prolonged period on intensive care (Wischmeyer, 2013). Losses are greater depending on the severity of illness and increasing number of failing organs (Puthucheary *et al.*, 2013). Loss of LBM can have negative implications on respiratory function and the ability to mobilise, and lead to increased number of days dependent on ventilation, risk of ventilator-acquired pneumonias, increased LOS on the ICU and increased mortality (Sharshar *et al.*, 2009).

Recommendations for target protein requirements range from 1.2 to 2 g protein/kg/day (Critical Care Nutrition, 2015; McClave *et al.*, 2016; Singer *et al.*, 2009). The available clinical trials are old and poorly designed. Many studies overfeed or underfeed energy, and often underfeed protein. Hoffer and Bistrian (2012) provide an excellent overview of the existing literature. Currently, the optimal protein requirements are not known; more recent observational studies are therefore guiding current practice in the absence of well-designed, high-quality RCTs. Weijs *et al.* (2014) suggested that a lower mortality is related to a >1.2 g/kg early protein intake. An analysis by Nicolo *et al.* (2015) found that ≥80% protein targets (1.2 g/kg) was associated with a favourable reduction in 60-day mortality. Importantly, this was independent of energy intake, which could indicate that protein is perhaps more important than energy provision in the early critical care phase. A promising dietetic-led RCT was recently conducted by Ferrie *et al.* (2016) with the aim of comparing standard protein intake with guideline recommendations for parenterally fed patients while crucially controlling for energy. Unfortunately this study did not achieve its aims, but identified an improvement in functionality (using handgrip) at 7 days. It was unfortunately underpowered, but similar studies assessing the impact of protein intake on measurements of functionality will help to define protein requirements in the critically ill.

In ICU patients, 1.2–1.5 g protein/kg/day should be aimed for, until further RCTs are published. This should be higher in patients with burns, trauma or increased losses. It is important to assess energy and protein requirements separately depending on the phase of critical illness. Protein modular supplements may need to be used to meet these targets without overfeeding energy. The EFFORT RCT is due to start data collection in 2018, randomising lower or higher protein intake in a large multinational trial which may provide clearer guidance for protein provision in the critically ill.

Nutrition support in obese patients

Assessing the energy and protein requirements of patients with obesity is one of the most problematic and controversial aspects of nutrition support. However, it is agreed that the aim should be a balance between the preservation of muscle mass and avoiding overfeeding and its harmful effects (McClave *et al.*, 2016). The controversy of using predictive equations largely stems from the altered body composition as compared to lean individuals (Kushner & Drover, 2011). Malnutrition can occur in all ICU patients irrespective of BMI, including obesity, as there is a misconception that the adipose stores represent additional nutritional reserves that can be depended upon in times of critical illness. This might not be the case, as the muscle loss observed was similar between those with and without obesity (Segaran *et al.*, 2015). Obesity should never be used as a rationale to withhold nutrition support. Deciding upon which weight to use is challenging as the actual weight does not reflect the amount of metabolically inactive body fat. As a result of the larger fat-free mass (Forbes, 1982, 1987), using ideal body mass (IBW) is likely to underestimate energy needs, and the use of actual body weight (ABW) will overestimate. The use of adjusted body weight (AdjBW) has been proposed (Amato *et al.*, 1995) on the assumption that the obese have a lean body mass that equates to 25% more than that of the non-obese. This approach has not been validated and is not recommended, as the original predictive equations were developed using ABW, and the use of AdjBW for predicting EE in obese patients will result in an underestimation (Frankenfield *et al.*, 2003). As most predictive equations are generated from non-obese patients, and body weight is one of the largest variables in these equations, estimation errors are common when predicting energy expenditure (Kushner & Drover, 2011).

The ASPEN/SCCM guidelines (McClave *et al.*, 2016) recommend that nutrition support not exceed 65–70% of target energy requirements as measured by IC. If IC is not available, they suggest 11–14 kcal/kg of ABW for those with a BMI of >30 kg/m^2, and 22–25 kcal/kg of IBW for patients with a BMI of >50 kg/m^2. These are expert consensus recommendations, and are based on the pooled findings of a small number of studies (Dickerson, 2004). Patients experienced shorter ICU lengths of stays and fewer antibiotic days when fed 11–14 kcal/kg of ABW as compared to those who received 19–25 kcal/kg ABW. This recommendation needs to be interpreted with caution, as only two studies are RCTs, only one was conducted in ICU patients, and all the studies were inadequately powered to evaluate major end points such as morbidity and mortality.

No randomised trials have evaluated a range of protein intakes, so the optimal protein requirements for obese patients remain unknown. The ASPEN/SCCM guidelines (McClave *et al.*, 2016) suggest 2 g/kg of IBW for those with a BMI of 30–40 kg/m^2, and 2.5 g/kg of IBW for those with a BMI of >40 kg/m^2. This is based on the same six trials of nutritional support in hospitalised patients

(Dickerson, 2004), as the energy recommendations have the same limitations. They demonstrated that at least 2 g/IBW is required to achieve neutral nitrogen balance. Further studies investigating the target protein intake for obese patients need to be undertaken. Until such time, expert guidelines should be consulted and clinical judgment used.

To conclude, a low-energy, high-protein strategy may not be applicable to all. Not all obese patients will have the same nutritional risk, with some benefiting from restriction while others need more. Individual patient assessment is necessary to assess the nutritional risk and help determine those who are most likely to benefit from nutrition support, as you would with non-obese patients. Predictive equations are inaccurate and can result in significant underfeeding and overfeeding. Indirect calorimetry (IC) remains the best way of ascertaining EE; however, if this is not available, the American guidance (McClave *et al.*, 2016) should be used as a starting place. If the low-energy, high-protein strategy is indicated, it can be challenging to achieve with the current enteral and parenteral formulas.

Feeding protocols

The use of ICU feeding protocols to promote early and safe enteral feeding is encouraged (McClave *et al.*, 2016). Units that follow simple algorithms are able to feed patients earlier and achieve energy goals sooner (Ventura & Waitzberg, 2015). Their use has been shown to increase the number of patients receiving EN; reduce the number receiving PN, or not being fed at all (Heyland *et al.*, 2004); and reduce hospital stay and hospital mortality (Martin *et al.*, 2004). The key to successful implementation is simplicity, as cumbersome protocols are more likely to be ignored or incorrectly applied. Although feeding protocols may vary between institutions, they have the following features in common:

- Aim to promote early, safe EN.
- Provide direction when managing gastric residual volumes (GRVs).
- Advocate use of prokinetics to improve tolerance.
- Recommend alternative routes of feeding if any intolerance persists, e.g. post-pyloric feeding or PN.

Nutrition support should be individualised to the metabolic demand over the different phases of critical illness (Preiser *et al.*, 2015). Therefore, protocols should only be followed for the initial period (e.g. up to 72 hours) before the critical care dietitian performs a nutritional assessment to identify which patients require individualised feeding plans.

Interruptions to feed

The unpredictable nature of critical illness and the medical management frequently lead to disruptions in the delivery of EN. In practice, it is rare for all the prescribed EN to be delivered. Large multicentre studies have found that ICU patients were uniformly underfed, with data from the International Nutrition Survey (2013), showing an average of 64% of energy and 60% of protein prescriptions being received over the first 4 days, increasing to 70% of energy and 60% of protein in those who remained in ICU for 12 days (Nicolo *et al.*, 2015). Frequently cited reasons include fasting for extubation, surgical and airway procedures, loss of access and GI intolerance (Kozeniecki *et al.*, 2016). The introduction of fasting guidelines has been shown to improve the delivery of nutrition (Segaran *et al.*, 2017). All efforts should be made to avoid unnecessarily prolonged fasting.

International guidelines (Critical Care Nutrition, 2015; McClave *et al.*, 2016) also recommend a volume-based feeding (VBF) approach using a daily feed target volume, empowering nursing staff to adjust feeding rates to make up for deficits encountered when interruptions occur. McClave *et al.* (2016) randomised 63 patients to volume-based or rate-based feeding and found that VBF significantly reduced energy deficits without any adverse effects. However, Heyland *et al.* (2016) compared VBF in 126 predominantly medical patients to 982 patients acting as controls. Both cohorts were underfed; the VBF group met 43% of energy requirements vs. 32% in the control group. There was a small improvement in nutritional delivery (8% increase in energy adequacy and 15% protein adequacy), which may not translate into improved clinical outcomes.

The introduction of VBF in UK ICUs is gaining popularity. This change in approach requires support from the ICU MDT. Nursing staff require comprehensive training to have the confidence to implement a new protocol and independently alter the feeding rate, traditionally dictated by a dietitian, protocol or medical team. Close monitoring of blood glucose levels and GI tolerance is required. In practice, inappropriately elevated feeding rates are occasionally calculated, which can lead to overfeeding.

Gastrointestinal dysfunction and enteral feeding intolerance

Critical illness frequently causes GI dysfunction, which contributes to feeding intolerance and poor EN delivery. A working group of the European Society of Intensive Care Medicine (ESICM) has developed useful consensus definitions and guidelines for GI dysfunction (Blaser *et al.*, 2012). Large GRVs have historically been used as a marker of gastric emptying and assumed to reflect EN intolerance. The incidence of feeding intolerance is 38% (5–75%), depending on the definition and threshold used for high GRVs (Blaser *et al.*, 2014; Gungabissoon *et al.*, 2014). The pathophysiology of GI dysfunction is multifactorial, including mechanical ventilation, sepsis, traumatic brain injury sedation, paralysing agents and vasopressors. Feeding intolerance is associated with fewer ventilator-free days, longer ICU stays and increased mortality (Gungabissoon *et al.*, 2014); GRVs are generally higher in more severely ill patients (Hsu *et al.*, 2011).

Significance of gastric residual volume

The reported values for the designated cut-off for withholding feed vary from 200 to 500 mL. The aims

of performing regular checks are risk reduction and/or prevention of pulmonary aspiration of gastric contents, which may result in pneumonia. However, GRVs may have little clinical meaning and do not consistently correlate with aspiration risk (McClave *et al.*, 2005), as increasing the GRV cut-off from 200 mL to 400 mL did not increase the risk of aspiration in predominantly surgical patients. Conversely, dropping the GRV cut-off from 400 mL to 200 mL failed to reduce the risk and protect patients from aspiration. The REGANE study (Montejo *et al.*, 2010) compared GRV cut-offs of 200 mL and 500 mL. The mean EN delivery was significantly higher in the intervention group, although the incidence of pneumonia, duration of mechanical ventilation and ICU length of stay were similar in both groups. The patients studied were predominately medical patients who are less likely to experience GI dysfunction.

Non-monitoring versus routine monitoring of gastric residual volumes

The multicentre study by Reignier *et al.* (2013) is the only RCT to evaluate if the risk of ventilator-related pneumonia (VAP) is increased when GRVs are not monitored, as compared to routine GRVs of >250 mL. The trial found no difference in the incidence of VAP between the groups; however, non-monitoring was associated with more vomiting. The nutritional adequacy was greater in the non-monitoring group, but the differences were minimal. Again, the patients were predominately medical rather than surgical, and not in multi-organ failure, so the results are unlikely to be generalisable to all ICU patients.

How frequently should gastric residual volumes be checked?

Williams and Leslie (2010) conducted an RCT comparing GRVs undertaken 4-hourly with variable GRVs of up to 8 hours. Vomiting and regurgitation was significantly increased in the variable checking group. No significant differences were found in the rates of VAP.

Returning or discarding of gastric residual volumes

One study has investigated whether returning GRVs up to 250 mL vs. discarding the GRVs resulted in better outcomes (Juvé-Udina *et al.*, 2009). There was no difference observed in ICU length of stay, diarrhoea, abdominal distention, nausea, vomiting or VAP between the two groups. Fluid balance and serum electrolytes were comparable and not different. There were less episodes of delayed gastric emptying in the return group. Overall, the study concluded that returning GRVs is not associated with more GI complications as compared to discarding them.

Practical application

Based on the evidence available, the rationale for routine GRV monitoring has been questioned; the 2016 ASPEN/SCCM guidelines (McClave *et al.*, 2016) advise that GRVs should not be used as part of routine care. This recommendation may be a little premature and not applicable to all, particularly surgical patients and those with multi-organ failure. The Critical Care Nutrition (2015) have adopted a more cautious approach, suggesting the use of 250–500 mL and a frequency of checking GRVs either 4-hourly or 8-hourly. The evidence for whether to return or discard GRVs is not compelling, and therefore decisions should be made at a unit-level in discussion with the MDT.

Prokinetic agent treatment

The use of prokinetic agents (metoclopramide, erythromycin and domperidone) has been suggested to help overcome feeding intolerance. However, studies have often been small and have methodological weaknesses, such as varying doses of drugs and a range of GRV cut-off values (Booth *et al.*, 2002). The most recent systematic review and meta-analysis (Lewis *et al.*, 2016) examined the efficacy and safety of prokinetic agents in critically ill patients receiving EN. It found that prokinetic agents significantly reduced feeding intolerance and the risk of developing high GRVs, and increased the success of post-pyloric feeding tube placement. However, the impact on other clinical outcomes such as pneumonia, mortality and ICU length of stay is unclear.

There are safety concerns regarding the use of prokinetic agents. Erythromycin, an antibiotic, has the potential to cause serious ventricular arrhythmia and microbial resistance to antibiotics (Booth *et al.*, 2002). Both metoclopramide and erythromycin should be used for the shortest duration required. Metoclopramide use should not exceed 5 days duration, owing to the risk of neurological adverse effects (European Medicine Agency, 2013). International guidance recommends metoclopramide as the first-line prokinetic in ICU due to safety concerns with erythromycin (Critical Care Nutrition, 2015; McClave *et al.*, 2016).

Reducing the risk of aspiration

Preventative measures include (McClave *et al.*, 2016) the following:

- Elevate the head of the bed to ≥45°.
- Consider using prokinetic agents.
- Use continuous enteral feeding.
- Consider the placement of a post-pyloric tube; regularly assess feeding tube placement to ensure that it has remained in the correct position.
- Consider using chlorhexidine mouthwash.

Post-pyloric enteral nutrition

Post-pyloric or small-bowel EN is often considered an effective way of overcoming large GRVs and therefore reducing the risk of aspiration; however, studies to support this assumption are limited. Nasoduodenal or nasojejunal tubes (NJT) are difficult to place and keep in the correct position; endoscopic placement can be time consuming and labour intensive. Self-propelling tubes are available; however, in one study, only 26–38%

of tubes placed in the stomach moved spontaneously into the duodenum, and the majority moved back into the stomach by retroperistalsis (Rees *et al.*, 1988). The use of a fluoroscopic technique to place tubes has been shown to be successful (Welpe *et al.*, 2010); others have achieved success with an electromagnetic tracking system (Taylor *et al.*, 2010).

There is conflicting advice regarding the use of NJTs. The ASPEN/SCCM guidelines (McClave *et al.*, 2016) support their use, while the older European guidelines (Kreymann *et al.*, 2006) concluded that the evidence does not justify general recommendations. Davies *et al.* (2012) found no significant increase in energy delivery with NJTs in patients with mildly elevated GRVs, and minor GI haemorrhage was increased. McClave *et al.* (2016) concluded that there is no difference in mortality or length of stay with small bowel feeding as compared to gastric feeding, despite the reduced risk of pneumonia. The studies described in both guidelines are small and report on differing outcomes. Despite this, more recent international guidelines recommend the use of post-pyloric feeding in those who are intolerant to gastric feeding, providing access can be easily gained.

Glycaemic control

Acute illness or injury may result in hyperglycaemia, insulin resistance and glucose intolerance, collectively termed as stress hyperglycaemia (Marik & Bellomo, 2013). It is thought to be an evolutionarily preserved adaptive response that allows the host to survive during periods of severe stress. Marik and Bellomo (2013) provide an excellent overview and explanations of the pathophysiological responses. Stress hyperglycaemia is not exclusive to patients with pre-existing diabetes, but appears to be related to the extent of critical illness. In most cases, it will resolve as the clinical condition improves.

Currently, there are two quite distinct views on glycaemic control during critical illness, and questions exist on whether tight glycaemic control is warranted. The early trial of van den Berghe *et al.* (2001) showed a significant reduction in the morbidity and mortality of surgical ICU patients with the aggressive use of insulin to maintain normoglycaemia. Favourable outcomes were attributed to the tight control of blood glucose as compared to a control group. It was concluded that this tight glycaemic control resulted in a reduction in mortality of 33% in surgical ICU patients. Since this publication, 14 independent prospective RCTs in various critically ill patient populations as well as a systematic review and meta-analysis (Yamada *et al.*, 2016) have been performed, and all demonstrate no outcome benefit from tight glycaemic control. The Normoglycaemia in Intensive Care Evaluation – Survival Using Glucose Algorithm Regulation (NICE SUGAR) trial (Finfer *et al.*, 2009) has been the largest trial to date, which demonstrated an increase in 90-day mortality in patients randomised to intensive insulin therapy. The type of feeding strategy employed in the trials fundamentally played a role. In the van den Berghe *et al.* (2001) study, participants were given large doses of intravenous glucose in addition to PN within 24 hours of admission, even in those who could tolerate EN. The findings of the NICE-SUGAR trial are more likely to be generalisable to those ICUs that use EN predominately. A moderate range of blood glucose management of 7–10 mmol/L is advised (Critical Care Nutrition, 2015; McClave *et al.*, 2016; Preiser, 2016).

Immune-modulating nutritional support

Enteral formulations

Immune-modulating enteral feeds are characterised by increased quantities of specific nutrients that may have the potential to improve immune function and modulate the inflammatory response. Such nutrients include arginine, n-3 polyunsaturated fatty acids, glutamine, ribonucleic acid (RNA) and antioxidants, including vitamin C and selenium. Currently, the use of immune-modulating EN is not recommended in international guidelines, and their use in UK clinical practice is still controversial. There is not sufficient evidence to support the use of these enteral feeds.

Specific nutrients

Fish oils

The addition of anti-inflammatory fish oils, eicosapentaenoic acid (EPA) and δ-linolenic acid (GLA), and antioxidants to EN has been used to potentially influence clinical outcome. A meta-analysis showed a reduction in mechanical ventilation and ICU days, as well as decreased risk of developing new organ failures and mortality in those who received the EPA/GLA EN (Pontes-Arruda *et al.*, 2008). The studies have several limitations inhibiting their applicability, e.g. lack of power calculations and/or blinding, short trial duration, the sickest patients being excluded, differing levels of EPA and GLA used, and a high-fat, low-carbohydrate control feed being used. More recent studies (Grau-Carmona *et al.*, 2011; Kagan *et al.*, 2015; Rice *et al.*, 2011; Stapleton *et al.*, 2011) have shown a lack of treatment effect. When all trials were aggregated, the use of an EN supplemented with fish oils and antioxidants did not significantly reduce ICU length of stay or the duration of mechanical ventilation or hospital stay as compared to a standard enteral formulation (McClave *et al.*, 2016). As a result, no recommendation for the use of these feeds can be made until further evidence is available.

Arginine

Arginine is one of the most controversial immunomodulatory nutrients. Studies show improvements in clinical outcomes and reduced mortality with arginine supplementation of enteral feeds (Atkinson *et al.*, 1998; Caparros *et al.*, 2001). Galban *et al.* (2000) assessed enteral arginine use in septic patients, finding reduced infections; however, benefits were only seen in patients with moderate critical illness, limiting generalisability to all. Greater mortality and an increase in the inflammatory response have been observed in severely septic patients (Bertolini *et al.*, 2003; Heyland & Samis, 2003). It is

proposed that, in severe sepsis, arginine may be converted into nitric oxide, contributing to haemodynamic instability and organ dysfunction. For this reason, recent international guidelines suggest caution or avoidance of arginine in severe sepsis (Critical Care Nutrition, 2015; McClave *et al.*, 2016).

Glutamine

Recent international guidelines (Critical Care Nutrition, 2015; McClave *et al.*, 2016) no longer support the routine supplementation of glutamine via the PN or EN route after considering the results of multicentre trials (REDOXS and Metaplus). The REDOXS trial (Heyland *et al.*, 2013) identified a trend towards increased mortality and no clinical benefit with the use of a high-dose (approximately 50 g per day) enteral and parenteral glutamine. However, glutamine was used in some patients with renal dysfunction, which is cited as a contraindication against the use of IV glutamine. The Metaplus trial (van Zanten *et al.*, 2014) supplemented EN with 30 g glutamine, plus selenium and fish oils, and found no difference in infectious complications or other secondary outcomes, as compared to standard practice and an increase in 6-month mortality.

Previously, benefits such as reductions in mortality, infectious complications, and ICU/hospital length of stay have been demonstrated (Déchelotte *et al.*, 2006; Wischmeyer, 2008). The reduction in infectious complications was seen in resolving multi-organ failure, smaller doses, and patients who were indicated PN and without renal or liver failure. There still remain questions regarding the appropriate dose, timing and route of glutamine; until the international community can be certain that supplemental glutamine does not cause any harm, glutamine should not be routinely used in the critically ill. The RE-ENERGISE trial is currently assessing the clinical outcomes and health-related quality of life regarding use of enteral glutamine on burns patients, with the results due in 2021.

Selenium and antioxidants

The plasma concentration of selenium and other antioxidants are reduced in septic patients, and are associated with a greater number of infectious complications and a higher incidence of mortality (Forceville, 2007). It is not clear if low plasma selenium concentrations are indicative of deficiency or normal metabolism during the acute-phase response. Manzanares *et al.* (2016) conducted a recent meta-analysis with high-dose selenium supplementation (>500 µg/day) and found no differences in mortality, infections, renal function or length of stay. However, a reduction in infectious complications was seen in non-septic patients who did not receive an initial IV bolus. Therefore, international guidelines do not recommend routine parenteral supplementation. More work is needed to determine the optimal dosage, route and frequency (if required at all) for selenium and other anti-oxidants such as zinc, ascorbic acid, vitamin E and beta-carotene before routine supplementation becomes common practice in critically ill patients.

Vitamin and mineral requirements

It is still not well understood if micronutrient requirements are significantly altered during critical illness. If aiming for an intake equal to the reference nutrient intake, the micronutrient needs of most patients can be met if target energy intakes are achieved. However, the target is rarely achieved during ICU stay. Hence, in those who consistently do not receive the target intake, supplementation of vitamins and minerals should be considered (van Zanten, 2015). Patients with major burns, high GI losses, and on continuous renal replacement therapy will have additional vitamin and mineral needs (Berger *et al.*, 2004). McClave *et al.* (2016) make a low-grade recommendation regarding the provision of antioxidant vitamins and trace elements, although they do not provide specific details on route, duration, dose or frequency.

Vitamin D

Interest in vitamin D is increasing as a high prevalence of deficiency (>50%) has been observed in critically ill patients (Amrein *et al.*, 2010). There is a growing body of observational data that describes the association between vitamin D deficiency and increased risk of 28-day mortality as well as sepsis (Moromizato *et al.*, 2014). One RCT has been performed with adequate power (VITdAL-ICU trial), randomising patients to an enteral loading dose followed by monthly or placebo doses (Amrein *et al.*, 2014). Although the trial did not find a difference in the primary outcome of hospital stay, there was a significant decrease in hospital mortality in those with severe deficiency (<30 nmol/L). At present, the data are insufficient to put forward a recommendation for the use of vitamin D supplementation in the critically ill.

Internet resources

American Society for Parenteral & Enteral Nutrition, www.nutritioncare.org

British Dietetic Association Critical Care Specialist Group, www.bda.co.uk

British Society for Parenteral & Enteral Nutrition, www.bapen.org.uk

Critical Care Nutrition, at the Clinical Evaluation Research Unit (CERU), www.criticalcarenutrition.com

European Society for Clinical Nutrition & Metabolism, www.espen.org

Intensive Care Society, www.ics.ac.uk

Scottish Intensive Care Society, www.scottishintensivecare.org.uk

Society of Critical Care Medicine, www.sccm.org

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7.17.2 Traumatic brain injury

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Key points

- A number of metabolic and physiological adaptations begin early in the acute phase of traumatic brain injury, but can persist long after rehabilitation.
- Early nutritional support is associated with better outcomes, and full nutritional requirements should be safely met within 5–7 days post-injury.
- Regular monitoring of anthropometry, biochemistry, feed tolerance and nutritional intake is essential to ensure appropriate nutritional management.
- A multidisciplinary approach is key throughout the acute and rehabilitation phases in order to manage the complex features that can influence nutritional status.

Traumatic brain injury (TBI) and head injury are terms that are used to describe an injury to the brain caused by a trauma to the head. Around 1.4 million people visit emergency departments each year in England and Wales following TBI, and, in 2013–2014, there were 162,544 admissions to UK hospitals, equating to 445 cases each day (NICE, 2014). The incidence of TBI is greater in males; men are 1.6 times more likely than women to be admitted to hospital. The primary causes of TBI include falls (22–43%), assaults (30–50%) and road traffic accidents (approximately 25%), with alcohol consumption considered to be involved in up to 65% of adult head injuries