Nutrition in the critically ill

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Nutrition

Summary

The aim of this article is to give an overview of the nutritional aspects in critically ill patients and summarise the latest guidelines and recommendations in establishing adequate nutritional support.

INTRODUCTION

Nutrition is an intrinsic part of critical care and evidence about effectiveness, timing, composition and route of administration has evolved considerably within the last 10-20 years. The understanding of the molecular and biological effects of nutrients in maintaining homeostasis in sick patients has contributed significantly.

Diets are composed of nutrients: *macronutrients* (protein, fats, carbohydrates and alcohol) and *micronutrients* (vitamins, minerals and trace elements). Malnutrition is caused by an imbalance (deficiency or excess) of energy, protein and other nutrients and leads typically to adverse effects on tissue/body form, function and clinical outcome. Undernutrition may be due to failure of food supply or intake, deliberate starvation or an illness and is characterised by weight loss and changes in body composition, with a relative increase in extracellular fluid volume.

Malnutrition/undernutrition is common in hospital patients worldwide and is present in over 40% of patients on admission in the UK.[1] Malnutrition is often unrecognized and is an independent risk factor for increased morbidity, increased length of hospital stay, delayed recovery, higher readmission rates, lower quality of life as well as increased hospital costs and higher mortality.[2]

Sepsis, trauma and major surgery cause complex metabolic and inflammatory reactions in the body. The metabolic picture of the stress response is characterized by catabolism, hypermetabolism, hyperglycaemia and increased lipolysis. This is caused by increased output of hormones that are counter-regulatory to insulin (catecholamines, cortisol, glucagon, growth hormone) and specific cytokines, such as interleukin-1 (IL^{-1}) and tumour necrosis factor (TNF). Skeletal muscle is used as an energy source.

DIAGNOSIS OF MALNUTRITION

Accurate estimation of the nutritional requirements in critically ill patients is challenging and traditional nutritional assessment tools have not been validated in critical care. Examples are:

Anthropometric measurements (e.g. skin fold thickness, mid-arm circumference). These are unreliable due to weight gain/loss, fluid shifts and oedema.

Biochemical tests

These have limitations:

- Albumin falls as part of the acute phase response,
- Haemoglobin may be affected by disease process, haemorrhage, transfusion, haemolysis, bone marrow suppression,

Body Mass Index

$$BMI = mass\ (kg)\ /\ height\ (m)^2$$

Although low BMI is a predictor of higher mortality in ICU, acute changes do not accurately reflect nutritional status.

General observation, a targeted history and examination of a patient for malnutrition is better then any specific test. Assessment should include evaluation of weight loss and previous nutrient intake before admission, disease severity, co-morbid conditions and gastrointestinal function.[3] One structured method that is widely accepted is the **Subjective Global Assessment (SGA)** (Table 1). As the name implies this is a subjective tool, however it is reproducible and correlates with mortality in a variety of conditions.[4] Assessment of nutritional status should also be used to identify patients at risk of re-feeding syndrome, which is described later in this article.

DOES NUTRITIONAL SUPPORT AFFECT PROGNOSIS?

The main goal in initiating nutritional therapy is to prevent or treat malnutrition/undernutrition among patients unable to sustain sufficient oral intake. The patients who are likely to benefit most are those who are already malnourished, who would otherwise undergo a long period of starvation, and who are therefore less able to tolerate further catabolism. However, for many clinical conditions, it remains unclear whether nutritional support is able to counteract the negative effects of malnutrition, or if the underlying disease itself renders substrate supplementation insufficient.

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Table 1.

Subjective Global Assessment		
History		
1	Weight change	Both chronic (over 6 months) and acute (over 2 weeks)
2	Changes in food intake	
3	Gastrointestinal symptoms	e.g. nausea, vomiting, diarrhoea and anorexia
4	Functional impairment	
Physical examination looking for:		
1	Loss of subcutaneous fat	Looking especially at the chest and triceps
2	Muscle wasting	Temporal region, deltoids and gluteal muscles
3	Oedema	
4	Ascites	

For some conditions, there are disease specific formulae to optimise the patient's nutritional status by managing nutrients, fluid and electrolytes, adjusted to the specific pathophysiological processes.

DOES A SHORT PERIOD OF STARVATION OUTCOME?

Critically ill patients are not a homogenous population and no single study that has evaluated the best timing for initiating nutritional support. There is now improved awareness about complications related to the use of enteral and parenteral nutrition, and the importance of improved control of blood glucose levels and delivery of reduced caloric loads.[5-8]

The gut is vulnerable to injury, especially ischemia and reperfusion, and also acts as an important immune organ due to its barrier function and reservoir of immune cells. However it contains potentially harmful microorganisms and it has often been postulated as 'the motor of multiple organ failure', by a process of bacterial translocation from the lumen to the blood stream.

The use of parenteral nutrition (PN) in ICU has declined markedly, in light of evidence that enteral nutrition (EN) may be generally superior in terms of clinical outcomes.[6-8] After reviewing all relevant studies, the European[9] and Canadian[10] clinical guidelines recommend starting enteral nutrition when the patient is adequately fluid resuscitated, within 24 hours or 24-48 hours respectively after admission to ICU. Early feeding provides a safety margin against failed attempts to establish feeding, it may reduce disease severity, diminish complications, decrease length of stay in the ICU and improve patient outcome.

WHAT ARE THE NUTRITIONAL REQUIREMENTS IN CRITICAL ILLNESS?

A careful balance of macronutrients (protein, lipid and carbohydrate) provides energy requirements, whilst micronutrients (vitamins and minerals) are required in very small amounts to maintain health but not to provide energy.

Macronutrients

The variability in resting energy expenditure makes it very difficult to predict caloric requirements. Both underfeeding and overfeeding can be harmful. Resting energy expenditure (REE) can be measured using indirect calorimetry and calculated using the Oxford equation,[11] which has now largely replaced the abbreviated Weir equation and the Harris Benedict equation. The Oxford equation gives lower estimated basal metabolic rate (BMR) values than its alternatives (including the Schofield equation, used in the WHO recommendations). There is little population data from China and Africa, so calculations cannot be validated for these populations.

These equations estimate BMR in afebrile healthy individuals and therefore needs to be modified in the following circumstances:

Fever Increase by 10% for each 1°C above 37°C (up to max of 40°C).

Sepsis Increase by 9% regardless of temperature

Surgery Increase by 6% if patient has had surgery or trauma

Burns Increase by 100% if any size over 30% (or use Toronto formula).

These factors are additive, so the energy requirements for a 33-year-old man (height 1.80m, weight 75kg), admitted after a laparotomy for a ruptured appendix and sepsis (temperature 39°C), work out to approximately 2460kcal.kg^{-1}.day^{-1} as follows:

25kcal.kg^{-1}.day^{-1} is generally recommended for most acutely ill patients. Protein requirements are determined and the remaining calories divided between glucose and lipid. During recovery the aim should be to provide values of 25-30kcal.kg^{-1}.day^{-1} to support the process of anabolic reconstitution.[12,13]

BMR	=	$(13.75 \times 75\text{kg}) + (5 \times 180\text{cm}) - (6.78 \times 33 \text{ years}) + 66$
	=	$1773.5 \text{kcal.day}^{-1}$
REE	=	1773.5×1.2 (add 20% for temperature) x 1.09 (for sepsis) x 1.06 (surgery)
	=	$2458.9 \text{kcal.day}^{-1}$ (i.e. roughly $2460 \text{ kcal.day}^{-1}$)

Failure to deliver at least 25% of calculated requirements is associated with worse outcome, however it is better to underfeed rather than attempt to match a calculated energy requirement, particular in sepsis and trauma.[14] The National Institute for Clinical Excellence (UK) has recommended that parenteral nutrition should be limited to a maximum of 50% or the calculated requirements for the first 48 hours after initiation.[15]

Predictive equations should be used with caution, as they provide a less accurate measure of energy requirement then indirect calorimetry. They are even more problematic in the obese patients. For all classes of obesity (BMI above 30), the goal of an enteral nutrition regime should not exceed 60-70% of target energy requirement or 11-14kcal.kg^{-1} actual body weight per day (or 22-25% kcal.kg^{-1} ideal body weight per day).[16]

The proportion of a feed made up by protein is sometimes expressed as a calorie: nitrogen ratio. 6.25g of protein contains 1g of nitrogen. The ratio is then calories (kcal) divided by nitrogen (g). Recommended calorie: nitrogen ratios are around 100:1 which will be achieved using the above figures. The optimal ratio for lipid:carbohydrate is not known.

Protein	• Provides 4kcal.g^{-1}
	• Around $1.5\text{g.kg}^{-1}.\text{day}^{-1}$ (range 1.2 to $2\text{g.kg}^{-1}.\text{day}^{-1}$ for ICU patients)
	• Use $2\text{g.kg}^{-1}.\text{day}^{-1}$ if severely catabolic e.g. severe sepsis, burns or trauma
	• Should be a mixture of essential and non essential amino acids
Lipid	• Provides 9.3kcal.g^{-1}
	• Calories from lipid should be limited to 40% of total calories
Carbohydrate	• Provides 3.75kcal.g^{-1} in vivo
	• 3 to $4\text{g.kg}^{-1}.\text{day}^{-1}$
	• Give the remaining energy requirements as carbohydrate

Micronutrients

Vitamins are organic compounds that usually act as cofactors for enzymes involved in metabolic pathways. Trace elements are ions that act as cofactors for enzymes or as structurally integral parts of enzymes and are often involved in electron transfer.

Effects of micronutrient deficiency

Zinc	Impaired T-cell function, reduced antioxidant defence, increased susceptibility to infection.
Copper	Reduced antioxidant defence, reduced tissue repair, increased susceptibility to infection.
Selenium	Reduced antioxidant defence, reduced tissue repair, increased susceptibility to infection
Thiamine	Impaired carbohydrate metabolism, neurological deficits
Riboflavin and Folic acid	Impaired immune function

Water and electrolytes

Water and electrolyte requirements vary between patients and regular assessment of hydration and correction of electrolytes is fundamental in critical care. Average daily requirements are:

Water	30ml.kg^{-1}
Na^+	$1.0 - 2.0 \text{mmol.kg}^{-1}$
K^+	$0.7 - 1.0 \text{mmol.kg}^{-1}$
Ca^{2+}	0.1mmol.kg^{-1}
Mg^{2+}	0.1mmol.kg^{-1}
Cl^-	$1.0 - 2.0 \text{mmol.kg}^{-1}$
PO_4^{2-}	0.4mmol.kg^{-1}

WHAT IS THE PREFERRED FEEDING METHOD IN A GIVEN SITUATION?

Any nutrition support, alone or in combination, needs to be commenced if the patient is already malnourished or at risk of malnutrition. Patients at risk include those who:

- have eaten little or nothing for more than 5 days and/or are likely to eat little or nothing for the next 5 days or longer, or

- have a poor absorptive capacity, and/or

- have high nutrient losses and/or

- have increased nutritional needs from causes such as catabolism.[14]

Potential swallowing problems should be taken into account.

Oral feeding is the optimal route of nutritional support. However most ICU patients are incapable or intolerant of oral diet and are therefore fed enterally or parenterally. Enteral nutrition is recommended over parenteral nutrition by practice guidelines in Europe and North America. This is based on numerous trials involving a variety of critically ill patients, including trauma, burns, head injury, major surgery and acute pancreatitis.[7,16]

Parenteral nutrition is indicated where enteral nutrition is contraindicated, for example in intestinal obstruction/perforation, non-functioning gut, gastrointestinal fistula, prolonged ileus, oesophageal/gastric surgery, perforation or malignancy.

TYPES OF NUTRITIONAL SUPPORT

Food fortification

This is the process of adding micronutrients to food.

Enteral nutrition

This can be either oral supplement or tube feeding:

Tube feeding	
Nasogastric	Most commonly used, depends on gastric emptying
	Allows use of hypertonic feed, high feeding rates and bolus feeding
Orogastric	Not suitable for awake patients
	In intubated patients to reduce sinusitis
Enterostomy (gastrostomy or jejunostomy)	Better for patients who require support for > 4 weeks
Post-pyloric feeding (nasojejunal or jejunostomy)	Avoids problem of gastroparesis
	Recommended if high risk of aspiration
	In major intra-abdominal surgery
	Intolerance of gastric feeding
	Acute pancreatitis

Parenteral nutrition (via either peripheral or central vein)

- *Peripheral access:* low osmolarity fluids only (<850mOsm.L^{-1}). Limited by large volumes needed to provide calories.

- *Central access:* solutions usually hypertonic.

ENTERAL NUTRITION

Enteral nutrition should be started within the first 24-48 hours of admission. It is also important to try to achieve the estimated caloric target within 48-72 hours. The use of enteral feeding protocols increases the overall percentage of goal calories provided since they avoid slow initiation and premature cessation of feed. An example is shown in Figure 1. If caloric and protein needs cannot be met by enteral feeding alone, parenteral feeding or a combination of both needs to be considered.

Important steps to ensure adequate enteral nutrition:

1. Confirm tube position (clinically and radiographically).

2. Secure tube well and check site regularly for potential tube dislodgment.

3. Start feeding early.

4. Aspirate regularly (4 hourly) and accept gastric residual volumes of 200-250ml. Adjust feeding rates accordingly. Once feeding is established this can be stopped.

5. Minimise aspiration risk via the following:
   - Patient should be head-up tilt at least 30°.
   - Avoid bolus feeds.
   - Use prokinetics early: metoclopramide 10mg IV 8 hourly +/- erythromycin 75mg IV 6 hourly.
   - Consider switch to post-pyloric tube feed.

6. Development of diarrhoea associated with tube feeding needs further evaluation.

Which enteral feed to use?

There are many commercially prepared feeds on the market, although these may not be available or affordable in many settings. The choice of feed will be influenced by the patient's requirements and underlying pathology. Most come as ready to use liquid microbial free preparations that contain all the necessary macro- and micronutrients as well as fluid and fibre. They are usually nutritionally complete within a specific volume, but expert dietetic advice should be sought. A ready to use standard feed will usually contain 1kcal and 0.04g protein per ml, but many other types of enteral feed preparations are available with differing energy:protein ratios and types of fat or protein.

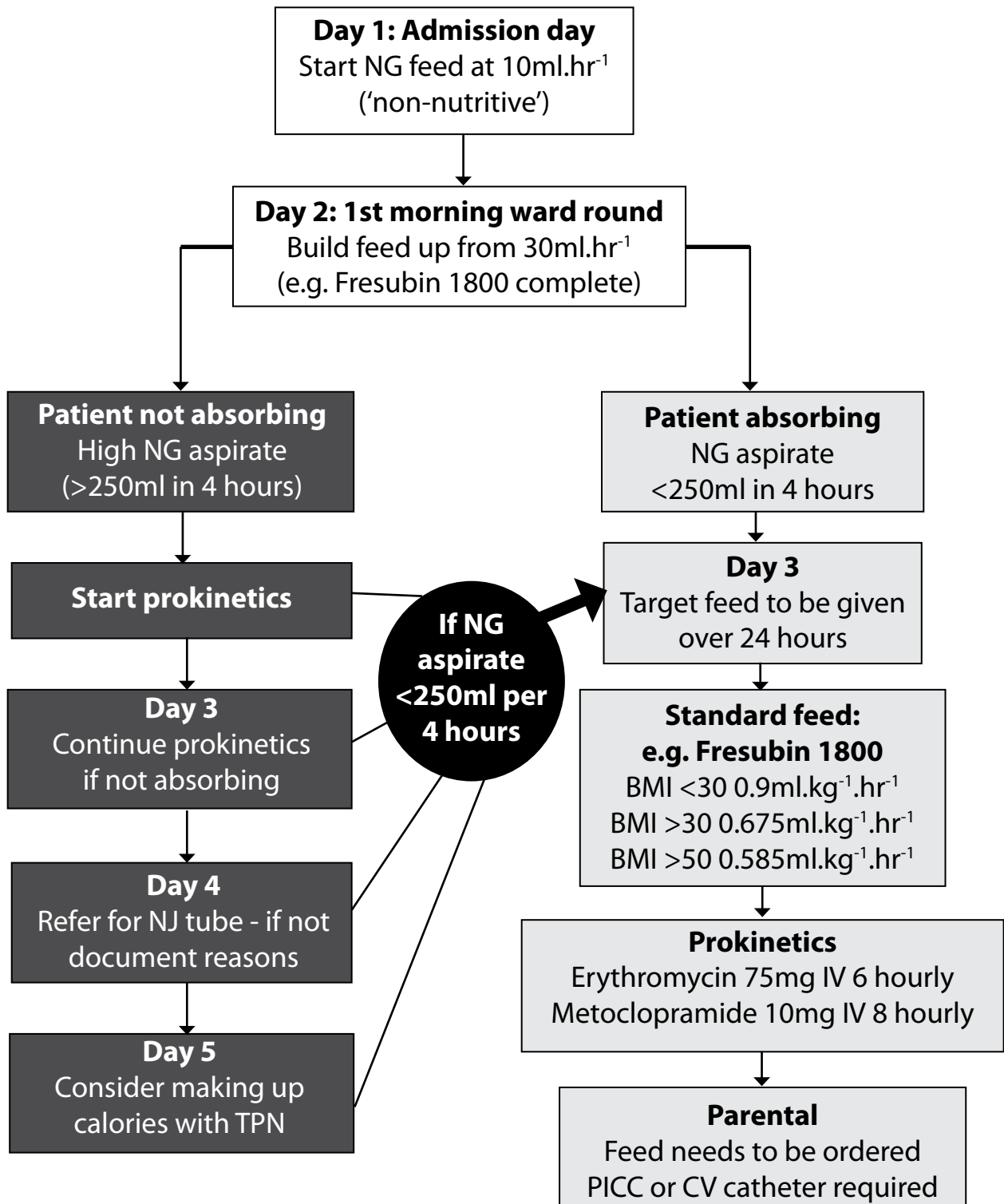The following feeds are generally used:

Hospital prepared feeds

Recipes vary according to country and available ingredients, but can include hard-boiled eggs, milk powder, soya, maize oil, rice, squashes, flour, sugar and fruit. These hospital-prepared feeds are much cheaper than commercially prepared feeds, but can block tubes and some recipes have been shown to give unpredictable levels of both macro- and micronutrients. In addition, they may contain contaminated ingredients and are not sterile. As a result, they must not be used for post-pyloric feeding or in patients with achlorhydria (insufficient gastric acid production). These feeds should only be used where commercial feeds are either not available or not affordable.

Polymeric preparations

These contain intact proteins, fats and carbohydrates (which require digestion prior to absorption), in addition to electrolytes, trace elements, vitamins and fibre. Fibre is broken down by colonic bacteria to produce a variety of compounds including butyric acid, an energy substrate for colonic enterocytes. These feeds tend to be lactose-free as lactose intolerance is common in ill patients. The different preparations vary in their osmolality, calorie to nitrogen ratio and carbohydrate to lipid ratio and can provide between 0.5 and 2kcal.ml^{-1} although

ICU Enteral Feeding Protocol

Day 1: Admission day
Start NG feed at 10ml.hr⁻¹
('non-nutritive')

↓

Day 2: 1st morning ward round
Build feed up from 30ml.hr⁻¹
(e.g. Fresubin 1800 complete)

Patient not absorbing
High NG aspirate
(>250ml in 4 hours)

↓

Start prokinetics

↓

Day 3
Continue prokinetics
if not absorbing

↓

Day 4
Refer for NJ tube - if not
document reasons

↓

Day 5
Consider making up
calories with TPN

If NG aspirate <250ml per 4 hours

Patient absorbing
NG aspirate
<250ml in 4 hours

↓

Day 3
Target feed to be given
over 24 hours

↓

Standard feed:
e.g. Fresubin 1800
BMI <30 0.9ml.kg⁻¹.hr⁻¹
BMI >30 0.675ml.kg⁻¹.hr⁻¹
BMI >50 0.585ml.kg⁻¹.hr⁻¹

↓

Prokinetics
Erythromycin 75mg IV 6 hourly
Metoclopramide 10mg IV 8 hourly

↓

Parental
Feed needs to be ordered
PICC or CV catheter required

Stop feed and aspirate stomach immediately before airway procedures or going to theatre.
Stop enteral nutrition on 2 hours prior to and post administration of enteral phenytoin.

Figure 1. *An example of an enteral feeding algorithm. Reproduced courtesy of Charlotte Battle, Chris Day, Sheena Hubble, Beth Thompson (Royal Devon and Exeter NHS Foundation Trust, UK).*

most are around 1kcal.ml^{-1}. Commonly used ingredients include the protein casein (from milk), soy protein, maize and soya oils and the carbohydrate maltodextrin. The vast majority of patients can be given standard polymeric feeds.

Elemental (pre-digested) preparations

These preparations contain the macronutrients in a readily absorbable form (i.e. proteins as peptides or amino acids, lipids as medium chain triglycerides and carbohydrates as mono- and disaccharides). They are expensive and only indicated for patients with severe malabsorption or pancreatic insufficiency. In patients with a short gut and no colon their high osmolality can cause excessive water movement and higher stoma losses.

Disease-specific formulae

These are usually polymeric and include feeds designed for:

Liver disease	Low sodium and altered amino acid content (to reduce encephalopathy).
Renal disease	Low phosphate and potassium. 2kcal.ml^{-1} rather than standard 1kcal.ml^{-1} to reduce volume.
Respiratory disease	High fat content (reduces CO_2 production).
Diarrhoea	Reduce fibre content.
Hypernatremia	Low sodium.
Catabolic state	High energy and high protein if lower volume feed needed.

Specific additives

Critical illness and injury are characterized by oxidative stress and excessive inflammation. There is a lot of interest in feeding formulas with specific pharmaconutrients that can help to moderate tissue damage and hold inflammation.

Antioxidants (vitamins A, C, E and selenium) stabilize free radicals in cells and hence reducing their potential for tissue damage. Where they can be sourced, a combination of antioxidant vitamins and trace minerals (specifically including selenium) should be provided to all critically ill patients. Dietary fish oils (mainly omega-3-fatty acids) are thought to blunt excessive inflammatory processes. Other immune modulating enteral nutrients such as arginine, glutamine and possible nucleotides have shown to lower the risks of infectious complications in certain patient groups, since they are thought to be depleted by stress of critical illness and injury.[17] Both the Canadian and European guidelines support the use of glutamine in burn and trauma patients.

In general these feeds tend to be more expensive and there is currently not enough data or a consensus to support their role in critically ill patients.

PARENTERAL NUTRITION

Parenteral feeding is the intravenous administration of nutrients. This may be supplemental to oral or tube feeding, or it may provide the only source of nutrition as total parenteral nutrition (TPN).

The only absolute indication for parenteral nutrition (PN) is gastrointestinal failure. All efforts to improve tolerance of enteral feeding such as the use of pro-kinetic agents and/or a post-pyloric feeding tube should be tried before starting PN. Patients receiving less than 25% of their predicted needs are at increased risk of sepsis and those who are intolerant of enteral nutrition, despite all attempts to improve this, should be considered for parenteral supplementation.

How much parenteral nutrition should critically ill patients receive?

During acute illness, the aim should be to provide energy as close as possible to estimated or measured energy expenditure in order to decrease the negative energy balance. In the absence of indirect calorimetry, ICU patients should receive 25kcal.kg^{-1}.day^{-1} increasing to target levels over the next 2–3 days.

PN can be given as separate components but is more commonly given as a sterile emulsion of water, protein, lipid, carbohydrate, electrolytes, vitamins and trace elements according to the recommendations discussed earlier regarding nutritional requirements. Standard formulations require thorough mixing before infusion. The electrolyte concentration can be altered for each patient and additional trace elements and vitamins may be added.

Protein

Protein is given as amino acids and needs to include essential amino acids. It should also ideally include most of the non-essential amino acids. Critical illness results in a relative deficiency of glutamine. In a number of small studies IV glutamine has been shown to improve survival and infection rates in patients on PN, particularly in trauma and burns patients. Glutamine supplementation is likely to be beneficial in patients receiving TPN for more than 10 days.

Lipid

This is commonly given as Intralipid®, an emulsion made from soya with chylomicron-sized particles. It provides a source of essential fatty acids, (linolenic acid, an omega-3 fatty acid and linoleic acid, an omega-6 fatty acid) and is a vehicle for delivery of fat-soluble vitamins. Lipid preparations are expensive and it is possible to give parenteral nutrition with low levels of lipid; giving 6% of total energy requirement as lipid is enough to avoid essential fatty acid deficiency.

If no parenteral lipid is given, vegetable oil should be massaged into the patient's limbs once a day; lipid is absorbed through the skin and may prevent or delay essential fatty acid deficiency, although requirements in critical illness may be too high for this to be sufficient. Watch for signs of deficiency: dry, scaly skin, with or without hair loss, and abnormal liver function tests. Most vegetable oils can be used (safflower, corn, soya, groundnut or sunflower) but not palm oil, as it contains virtually no linolenic acid. Fat-soluble vitamins will need to be given separately.

Carbohydrate

Carbohydrate is given as glucose. The minimal amount of carbohydrate required is about 2g.kg^{-1} glucose per day. It should provide approx 60% of non-protein calories.

Electrolytes and micronutrients

Critically ill patients are prone to fluid and sodium overload, and renal dysfunction is frequent. The exact electrolyte requirement needs to be determined by close plasma electrolyte monitoring and should not be a fixed element of parenteral nutrition prescription.

Patients with sepsis have been shown to have large vitamin A losses in their urine, burns patients lose selenium, zinc and copper via their exudates and trauma patients lose selenium and zinc through their drains. Selenium impairs the role of glutathione peroxidase as a free radical scavenger and selenium supplementation may be helpful in general ICU patients.

Monitoring

The following schedule is recommended for all patients receiving parenteral nutrition:

- Baseline level for FBC, B_{12} and folate, electrolytes and creatinine, magnesium, phosphate, calcium and glucose; LFTs, albumin, prealbumin, C-reactive peptide (CRP), zinc and copper.

- Blood glucose every 4-6 hours.

- Daily FBC, electrolytes and creatinine. Magnesium and phosphate should be measured if there is a high risk of refeeding syndrome.

- Liver function tests, lipid profile, calcium, albumin, prealbumin, transferrin and CRP once/twice weekly.

- Zinc, iron, selenium and copper levels every 2-4 weeks.

- Manganese and 25-OH-vitamin D levels 3-6 monthly.

The frequency of these tests is dictated by local availability and can be reduced once the patient's condition is stable.

When should parenteral nutrition be initiated?

Current guidelines regarding the timing differ.[18] For patients who cannot be enterally fed, the European guidelines recommend starting PN within 24 to 48 hours, if the patient is not expected to be on oral nutrition within 3 days.[18] US guidelines recommend standard care (IV fluids) first and PN initiated only after 7 days in well-nourished patients.[16] Both guidelines recommend starting PN within 24 hours of admission in patients who are malnourished.

Should we combine enteral and parenteral feeding?

When enteral feeding alone is inadequate, experts have advocated using PN and EN together to meet the energy and protein targets.[18] Clinical evidence for combined feeding and when to start additional PN remains unclear. Two recent randomised trials tried to clarify this subject, but the evidence remains controversial. The key conclusions are that supplemental parenteral nutrition should not be started on admission, but subsequently may improve outcome in patients with a high mortality risk.[20,21]

COMPLICATIONS OF NUTRITIONAL SUPPORT

Re-feeding syndrome

Patients who are severely malnourished, or have undergone a significant period of starvation, are at risk of refeeding syndrome during the first few days of nutritional support, regardless of the route of administration. Starvation causes a loss of intracellular electrolytes secondary to leakage and reduced transmembrane pumping. Intracellular stores can become severely depleted even though serum levels may be normal. When carbohydrate is available again there is an insulin-dependent influx of electrolytes into the cells, which can result in rapid and severe drops in serum levels of phosphate, magnesium, potassium and calcium. There is also a risk of lactate acidosis secondary to conversion of pyruvate. The clinical features include oedema, weakness, diarrhoea, respiratory failure, cardiac failure, arrhythmias, seizures, coma and death.

Risk factors for re-feeding syndrome

Two or more of the following:

- BMI less then 18.5 kg.m^{-2}

- Unintentional weight loss >10% within last 3-6 months (>15%)

- Little or no nutritional intake for more than 5 days

- History of alcohol abuse or drugs including insulin, chemotherapy, antacids or diuretics

- Critically low levels of phosphate, potassium and magnesium.

At risk patients should be identified and feeding must be introduced slowly, starting with 5-10kcal.kg^{-1}.day^{-1} and gradually increasing after 4 to 7 days. Circulatory volume must be restored and the above electrolytes should be generously supplemented at the same time as starting feeding and should be closely monitored. Thiamine and other B vitamins should also be given intravenously before starting feeding and then daily for at least three days.

Overfeeding

Deliberate overfeeding, in an attempt to reverse catabolism, is ineffective and is associated with a poor outcome. Overfeeding causes uraemia, hyperglycaemia, hyperlipidaemia, fatty liver (hepatic steatosis) and hypercapnia (especially with excess carbohydrates), with difficulties in weaning from ventilatory support and fluid overload. It is probable that at least some of the risks of parenteral nutrition are actually related to overfeeding and NICE (UK) recommend that PN should be limited to a maximum of 50% of the requirements for the first 48 hours after initiation.[15]

Commencing high levels of feeding shortly after major surgery, in severe sepsis or multiorgan failure can cause insulin resistance and other metabolic problems similar to those of refeeding.

Propofol (either 1% or 2%) is formulated in 10% Intralipid and this must be included in the calculations for nutritional support.

Hyperglycaemia

Hyperglycaemia worsens outcome in the critically ill, and is more commonly caused by insulin resistance secondary to the stress response, than overfeeding.

Strict glucose control, keeping serum glucose levels between 80 and 110mg.dl^{-1}, was associated with reduced sepsis, reduced ICU length of stay and lower hospital mortality when compared to conventional insulin therapy, keeping blood glucose levels <200mg.dl^{-1}.[22] The effect was more pronounced in surgical than medical patients. However the recent NICE Sugar trial suggested that moderate control (blood glucose levels between 140 and 180mg.dl^{-1} [7.8-10mmol.L^{-1}]) might avoid problems of hypoglycaemia and subsequently reduce mortality compared to tighter control.[23]

The optimal target range for blood glucose in the critical ill patients remains unclear, but the general consensus is to maintain glucose within the range of 6-10mmol.L^{-1}.

Specific complications of enteral nutrition

The commonest risk with enteral feeding is aspiration of feed causing pneumonitis. The implementation of a combination of measures including feeding protocols, nurse education programmes and good oral hygiene has been shown to decrease the risk of ventilator-associated pneumonia. Diarrhoea can also be a problem but is not an indication to stop feeds. Other causes of diarrhoea need to be excluded but if enteral feeds are the cause then a feed with more fibre can be tried.

Insertion	Mucosal damage, pharyngeal/oesophageal pouch perforation, intracranial insertion, bronchial placement, variceal bleeding
PEG/PEJ insertions	Bleeding, bowel perforation
Post insertion	Discomfort, erosions, fistulae, strictures
Displacement	Tube falls out, bronchial administration of feed
Reflux	Oesophagitis, aspiration, ventilator associated pneumonia
Feed intolerance	Nausea, bloating, pain, diarrhoea
Metabolic	Refeeding syndrome, hyperglycaemia, hypercapnia, fluid overload, electrolyte disturbance

Specific complications of parenteral nutrition

Access related

The insertion and presence of a central venous catheter has inherent risks including pneumothorax, haemothorax, arterial or nerve damage, infection, central vein thrombosis and erosion through the wall of the vein or right atrium.

Infusion related

It is thought that some of the increased risk of sepsis seen in patients receiving parenteral nutrition has actually been the result of overfeeding and uncontrolled hyperglycaemia, rather than due to parenteral nutrition itself. Rebound hypoglycaemia with sudden cessation of PN infusions may occur and regular blood glucose checks are essential. Refeeding syndrome, especially in malnourished patients, has a high morbidity and mortality and the feeding protocol needs to be adjusted as discussed earlier.

Infection is a serious risk and the bags must be sterile and discarded within 24 hours of initiation of use. Sterile precautions must be used for bag changes and the lumen of the central venous line must not be used to take blood or give drugs or fluids (this may also result in precipitation of the emulsion).

Parenteral nutrition also predisposes to hepatobiliary disease including fatty liver, cholestasis and acalculous cholecystitis. Great care must be taken to avoid electrolyte imbalances and micronutrient deficiencies particularly in those requiring nutritional support for prolonged periods. If lipaemia becomes a significant problem the rate of PN can be reduced or the lipid component reduced or removed.

Related to deficiencies

All vitamins and trace element deficiencies can develop. Thiamine deficiencies can cause lactate acidosis, wet or dry beriberi, whilst the lack of vitamin K may predispose to an increase bleeding risk. Patients on renal replacement therapy will need water-soluble vitamins replaced.

SUMMARY

Malnutrition/undernutrition is common and associated with a poor outcome in critical illness. Enteral nutrition is the preferred method of feeding and important in counteracting the catabolic state seen in severe disease states. It should be started during the first 24-48 hours in all patients in whom it is safe to do so, using a standard high protein formula. Total energy intake should be measured or estimated, however 25kcal.kg^{-1} of usual body weight per day is adequate for most patients. Enteral feeding is not without risks, but these can be significantly reduced with simple measures, and adherence to feeding protocols.

Supplementary parenteral nutrition should be given only to those patients who do not reach their target nutrient intake on enteral nutrition alone. There is no general indication for immune-modulating formulae in patients with severe illness or sepsis. Glutamine should be supplemented in patients suffering from burns or trauma. In all patients receiving nutritional support it is vital to maintain moderate glucose control with insulin therapy. Overfeeding should be avoided.

REFERENCES

1. McWhirter JP, Pennington CR: Incidence and recognition of malnutrition in hospital. *BMJ* 1994; **308**: 945.

2. Stratton RJ, Green CJ, Elia M. Disease-related malnutrition: an evidence-based approach to treatment. CAB International 2003.

3. Martindale RG, McClave SA, Vanek VW et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition: Executive Summary. *Crit Care Med* 2009; **37**: 1757-61.

4. Detsky AS, McLaughlin JR, Baker JP et al. What is subjective global assessment of nutritional status? *J Parenter Enteral Nutr* 1987; **11**: 8–13.

5. Ziegler TR Parenteral nutrition in the critically ill patient. *N Engl J Med* 2009; **361**: 1088-97.

6. Thibault R, Pichard C Parenteral nutrition in critical illness:can it safely improve outcomes? *Crit Care Clin* 2010; **26**: 467-80.

7. Heyland DK, Dhaliwal R, Drover JW, Gramlich L, Dodek P, Canadian Critical Care Clinical Practice Guidelines Committee. Canadian clinical practice guidelines for nutrition support in mechanically ventilated, critically ill adult patients. *J Parenter Enteral Nutr* 2003; **27**: 355-73.

8. Heighes PT, Doig GS, Sweetman EA, Simpson F An overview of evidence from systematic reviews evaluating early enteral nutrition in critically ill patients: more convincing evidence is needed. *Anaesth Intensive Care* 2010; **38**: 167-74.

9. Kreyman KG, Berger MM, Deutz NE et al. ESPEN Guidelines on enteral nutrition: intensive care. *Clin Nutr* 2006; **25**: 210-23.

10. Heyland DK, Schroter-Nope D, Drover JW et al. Nutrition support in the critical care setting: current practice in Canadian ICUs – opportunities for improvement? *J Parenter Eneral Nutr* 2003; **27**: 74-83.

11. Henry CJK. Basal metabolic rate studies in humans: measurements and development of new equations. *Public Health Nutrition* 2005; **8**: 1133-52.

12. Shizgal HM, Martin MF. Caloric requirement of the critically ill septic patient. *Crit Care Med* 1988; **16**: 312-7.

13. Kreymann K G et al. ESPEN guidelines on Enteral Nutrition: Intensive care. *Clinical Nutrition* 2006; **25**: 210–23.

14. Campbell Edmondson W. Nutritional support in critical care: an update. *Continuing Education in Anaesthesia*, *Critical Care and Pain* 2007; **7:** 199-201.

15. Nutrition support in adults. www.nice.org.uk/CG032

16. Mcclave S A, Martindale R G et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient. *J of Parenteral and Enteral Nutrition*. 2009; **33**: 277-316.

17. Mizock BA. Immunonutrition and critical illness: an update. *Nutrition* 2000; **26**: 701-7.

18. Singer P et al. Considering energy deficit in the intensive care unit. *Curr Opin Clin Nutr Metab Care* 2010; **13**: 170-6.

19. Singer P et al. ESPEN guidelines on Parenteral Nutrition in Intensive Care. *Clin Nutr* 2009; **28**: 387-400.

20. Casaer MP, Mesotten D, Hermans G, Wouters PJ, Schetz M, Meyfroidt G et al. Early versus late parenteral nutrition in critically ill adults. *N Engl J Med* 2011; **365**: 506-17.

21. Singer P, Anbar R, Cohen J, Shapiro H, Shalita-Chesner M, Lev S et al. The tight calorie control study (TICACOS): a prospective, randomized, controlled pilot study of nutritional support in critically ill patients. *Intensive Care Med* 2011; **37**: 601-9.

22. Van den Berghe G et al. Intensive insulin therapy in the critically ill patients. *N Engl J Med* 2001; **345**: 1359-67.

23. NICE-Sugar Study investigators. Finfer S, Chittock DR, Su SY, Blair D, Foster D, Dhingra V et al. Intensive versus conventional glucose control in critical ill patients. *N Engl J Med* 2009; **360**: 1283-96.