The Importance of Nutrition in Critically Ill Children

Shannon Hartell, Senior Specialist Paediatric Critical Care Dietitian, Evelina London Children's Hospital, United Kingdom (UK)

Paediatric critical illness is characterised by a systemic inflammatory response triggered by injury, infection or trauma, including surgery. This results in significant metabolic and endocrine adaptations that evolve through the distinct phases of critical illness.[1]

Introduction

In 2023, the UK recorded an average of 50 Paediatric Intensive Care Unit (PICU) admissions per day, with approximately 40% of these children being younger than a year old.[2] That same year, the mortality rate amongst PICU admissions was 3.7%, accounting for 16.6% of all childhood deaths in the country.[2] These figures underscore the importance of targeted nutritional interventions to improve survival and recovery rates.

Nutrition plays a critical role in determining short- and long-term outcomes for critically ill children admitted to the paediatric intensive care unit (PICU).[3] Research has demonstrated that adequate and appropriate nutrition support can significantly enhance patient recovery, reduce the length of hospital stay, and reduce morbidity and mortality risk.[3-6]

Undernutrition has been shown to prolong hospitalisation, and this risk is further exacerbated for critically ill children with limited nutritional reserves and increased metabolic demands.[5] In the UK, the average PICU stay is 2.8 days; however, in 2023, 3.92% of PICU admissions had stays exceeding 28 days.[2]

Effectively managing nutrition in critically ill children demands a nuanced understanding of the different phases of critical illness and their implications for nutritional goals, alongside an awareness of the unique nutritional challenges posed by the intensive care environment.[4, 5, 7] The European Society of Paediatric and Neonatal Intensive Care (ESPNIC) released a position statement in 2020 detailing recommendations for nutritional provision, overcoming nutritional barriers in the PICU and supporting recovery post-discharge.[8, 9] This position statement provides guidance for individuals working on PICU and supports improving patient outcomes.

This article explores the intricate relationship between nutrition and critical illness, highlighting challenges faced and strategies to meet the nutritional needs of critically ill children, with a focus on evidence-based recommendations and their impact on recovery and development.

Nutrition & critical illness

The physiological changes that occur during critical illness evolve through three phases: acute, stable and recovery.[1, 7, 10] These phases are explored in detail below.

The acute phase

Also referred to as the resuscitation phase or shock, this phase marks the onset of critical illness and is characterised by significant metabolic and endocrine changes. This involves a pronounced shift to catabolism and the requirement for vital organ support; typically, mechanical ventilation, fluid resuscitation, and pharmacological treatments such as sedation or inotropic support.[5, 11]

The metabolic response in the acute phase is driven by neuroendocrine adaptations, including resistance to insulin and growth hormone (GH). These changes promote catabolic processes, including proteolysis, lipolysis, glycolysis and glycogenolysis to mobilise nutritional stores. Substrates, including amino acids, free fatty acids and glycogen, are utilised for endogenous energy production via gluconeogenesis and the synthesis of acute phase proteins, including C-reactive protein (CRP).[4, 10]

During the acute phase, the inactivation of growth factors and resistance to GH inhibit normal growth.[5, 10, 11] Additionally, the combination of reduced energy expenditure, secondary to sedation and mechanical ventilation, and the inhibition of growth reduces the energy requirements during this phase. The consequences of insulin resistance and gluconeogenesis during this initial stress response, including hyperglycaemia and hypertriglyceridemia, further emphasises the importance of avoiding overfeeding in the acute phase response. Despite the reduced energy needs, provision of sufficient protein is essential to maintain a positive nitrogen balance and preserve lean body mass.[6]

The stable phase

The stable phase, as the name suggests, is characterised by stabilisation. This is the initial stage of stabilising on or weaning of vital organ support, and resolution of the acute inflammatory response.[7, 11] The reduction in inflammatory proteins, including CRP, and the normalisation of anabolic hormones are key characteristics of this phase, and indicates the transition from catabolism toward anabolism.[1]

An incremental approach to increasing nutrition provision during the stable phase can be preventative for under- and over-feeding. During this phase, ongoing muscle breakdown and weakness due to immobilisation underscores the need for adequate protein and energy provision.[1]

The recovery phase

The final phase of critical illness, also referred to as the rehabilitation phase, is characterised by patient mobilisation and the normalisation of metabolic and endocrine processes. During this phase, protein synthesis exceeds breakdown, and energy requirements may be up to two times the resting energy expenditure (REE).[1, 6]

The primary aim of nutrition in the recovery phase is to support nutritional rehabilitation, rebuild lean body mass, and achieve catch up growth in cases of faltering growth.[6]

Nutritional requirements for the phases of critical illness

The gold standard for determining energy requirements for critically ill children after the acute phase is indirect calorimetry (IC), however, in the absence of IC, predictive equations may be utilised.[1, 8, 9] The preferred predictive equation for energy calculation is the Schofield Equation as per ESPNIC.[5, 8, 9] Stress and activity factors can be incorporated into energy calculations depending on the phase of critical illness.[6]

While predictive equations assist in estimating energy needs, the American Society for Parenteral and Enteral Nutrition (ASPEN) provides specific recommendations to ensure adequate protein and caloric intake. This includes a minimum protein and energy intake of 1.5 g/kg/day protein and approximately 58 kcal/kg/day to maintain a positive nitrogen balance.[1] This translates to a protein-energy ratio of approximately 10%. Protein requirements need to be adapted according to clinical status. The recommended upper limits of protein are 3 g/kg/day of protein in infants and children, and 2 g/kg/day for adolescents.[5]

Tables 1 & **2** summarise energy requirements for the phases of critical illness.

Table 1: The Schofield Equation

Schofield's Equation for calculating REE (kcal/day)		
Age	Boys	Girls
0-3 years	59.9 x (wt in kg) - 30	58.3 x (wt in kg) - 31
3-10 years	22.7 x (wt in kg) + 504	20.3 x (wt in kg) + 486
10-18 years	17.7 x (wt in kg) + 658	13.4 x (wt in kg) + 692

Stress Factors: • Acute: 1.0 x REE • Stable: 1.3 - 1.5 x REE • Recovery: 1.5 x 2.0 x REE

Table 2: ESPGHAN PN Energy Guidelines 2018

ESPGHAN PN (kcal/kg/day)			
Age	ACUTE	STABLE	RECOVERY
0-1 year	45-50	60-65	75-85
1-7 years	40-45	55-60	65-75
7-12 years	30-40	40-55	55-65
12-18 years	20-30	25-40	30-55

Micronutrient considerations

Currently, no specific recommendations for micronutrient requirements exist for critically ill children.[3, 12] However, micronutrient intakes should align with reference nutrient intakes (RNI) for age, with deficiencies corrected as required.

Critical illness induces significant metabolic changes, often leading to altered serum levels of micronutrients due to physiological adaptation, redistribution, or dilution. These fluctuations can complicate assessments, making cautious interpretation of results is essential.[12]

Among the most commonly observed deficiencies in critically ill children is vitamin D, and supplementation is an important consideration in this high-risk patient group. Similarly, zinc, selenium and iron are often reduced in critical illness as a result of the inflammatory response.[12, 13]

Given these nutrient alterations, maintaining adequate micronutrient intake through enteral nutrition or parenteral nutrition (PN) is essential to mitigate complications and support recovery.

Challenges in providing nutrition

Challenges in providing nutrition on PICU vary between units, but common barriers affect the timely achievement of nutritional goals. Among the most prevalent challenges are delayed initiation, feeding interruptions and fasting for procedures. It is recommended that enteral feeding is initiated within the first 24-48 hours of PICU admission. This may be delayed due to haemodynamic instability, need for fluid resuscitation, or a lack of available fluid for feeds. These factors may warrant a delay in feeding initiation. However, in the absence of haemodynamic instability, feeding should commence progressively to meet two-thirds of nutritional goals within the first week.[8, 9]

The most common cause of feed interruption due to perceived feed intolerance is large gastric aspirates or gastric residual volumes (GRVs). GRVs are obtained by aspirating stomach contents via a nasogastric tube to assess feed tolerance. However, this practice often leads to unnecessary feed interruptions and delays in enteral feeding progression. It is often not a true indication of feed intolerance and is subjective in its measurement.[14] Variations in practice for obtaining gastric aspirates, a lack of evidence to support the validity of its use, and the impact this practice has on achieving nutritional goals has resulted in the launch of a nationwide randomised control study. The GASTRIC-PICU study is ongoing and aims to challenge this embedded PICU practice.[15, 16]

Beyond gastric aspirates, another major barrier to enteral feeding is gastric dysmotility, which affects nearly 50% of PICU patients. This complex phenomenon refers to a functional impairment of the gastro-intestinal tract, an abnormally slow or uncoordinated activity of the gastric or duodenal musculature. Gastric dysmotility can lead to delayed gastric emptying, causing feed intolerance, gastro-oesophageal reflux, and an increased risk for aspiration and, subsequently, ventilator associated pneumonia (VAP). Sedatives and paralytic agents are associated with worsened gastric dysmotility and can lead to constipation, which is defined as bowels not opening for three or more days.[17, 18] Use of pro-motility agents, managing constipation, use of peptide feeds when polymeric feeds are not tolerated, and post-pyloric feeding where gastric feeding is contraindicated, may be considered in patients who are unable to progress with enteral feeding.[8, 9, 18] When these interventions are unsuccessful, PN may be considered.

Parenteral nutrition

PN may be lifesaving for children in PICU who cannot meet their nutritional goals through enteral feeding due enteral feeding failure or contraindications. However, the risks associated with PN must be carefully considered. These include line-associated risks (infections, occlusion, extravasation injuries and loss of access), cholestasis, metabolic bone disease and refeeding syndrome.[19] Given the risks, the timing of PN initiation requires thoughtful decision-making.

Historically, PN was often initiated early to prevent malnutrition, however, the PEPaNIC (Early versus Late Parenteral Nutrition in the Pediatric ICU) trial demonstrated that withholding PN for the first seven days of PICU admission results in better clinical outcomes. This multi-centre, randomised control trial that compared early versus late PN initiation and found that delaying PN for the first week resulted in fewer new infections, shorter duration of mechanical ventilation and a reduced hospital stay when compared with providing PN within the first 24 hours.[20-22]

Its findings have led to a paradigm shift in paediatric critical care nutrition, influencing global best practices, including the ESPGHAN (European Society for Pediatric Gastroenterology Hepatology and Nutrition) 2018 paediatric PN guidelines and the ESPNIC 2020 position paper on nutritional support for children during critical illness.[8, 9, 23] These guidelines continue to shape international recommendations on PN use in PICU settings.

Nutrition support following discharge from PICU

Nutrition support for children discharged from PICU is crucial to ensure that their nutritional demands of the recovery phase are met. Supplementary enteral feeding or provision of oral nutritional supplements are often necessary to achieve adequate intake, particularly for those who have experienced significant weight loss. Nutrition education with a focus on food fortification strategies to improve protein and energy intake is especially important to support catch up growth.[8, 9]

Beyond nutritional rehabilitation, feeding challenges are common post-PICU admission. Complications such as food refusal, reduced appetite, changes in food or taste preferences and oral aversion may arise due to prolonged PICU stay.[3] The psychological impact of PICU admission and parental anxieties related to feeding can also complicate recovery, and behavioural interventions play a vital role in normalising feeding behaviours.[3]

A multi-disciplinary approach is essential for optimising long-term recovery. Children who experience dysphagia, oral aversion, or reliance on enteral feeding benefit from speech and language therapy to facilitate safe oral feeding progression.[24]

Appropriate follow-up, whether hospital- or community-based, is essential for monitoring growth and nutritional status, and the multi-disciplinary team needs to work together to accommodate metabolic and functional changes experienced following paediatric critical illness.[8, 9]

Conclusion

Effective nutritional management is crucial for improving survival, recovery and the long-term health outcomes in critically ill children. Tailoring nutrition strategies to each phase of illness allows healthcare providers to effectively manage the complex metabolic challenges of the PICU environment

Ongoing research and regular evaluation of best practices are vital for refining guidelines and enhancing paediatric patient outcomes.

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