به نام خدا

Nutrition
In
PICU

A pediatric intensive care unit (also paediatric), usually abbreviated to PICU is an area within a hospital specializing in the care of critically ill infants, children, and teenagers

The ratio of professionals to patients is generally higher than in other areas of the hospital, reflecting the acuity of PICU patients and the risk of life-threatening complications

PICUs have a larger operating budget than many other departments within the hospital

Goran Haglund is credited with establishing the first pediatric ICU in **1955**. The PICU was located at Children's Hospital of Goteburg in Sweden

- The nurses and physicians **must work together** as a collaborative team to provide optimal care
- The successful collaboration between ***all team members*** has resulted in **lower mortality** rates not just in PICUs, but all intensive care units
- The PICU care team includes many different roles. (physicians, nurses, pharmacists, respiratory therapists, child life, intensivists, cardiologists, physical / occupational therapists, social workers) Each member of the inter-professional team are highly skilled and trained to deliver the best care for each and every child.

Poor Outcomes in PICU Patients

- The main factor that leads to inadequate care for PICU patients is **improper health assessment** by the healthcare providers
- Challenges of Working in the PICU result may in ***emotional stress***

- ***Delivery of adequate nutrition intake is an essential component of pediatric intensive care***.
- Optimal nutrient intake during critical illness helps offset energy expenditure and protein catabolism and prevents nutrition deterioration during this vulnerable period.
- ***Cumulative energy and protein deficits*** are associated with deterioration in anthropometrics at discharge and may be associated with ***increased morbidity and mortality in critically ill children***
- **The optimal delivery of nutrients requires accurate estimation of requirements**

- Critical illness is characterized by ***protein catabolism***, which may result in negative protein balance in cases where intake does not offset these losses. ***Undesirable muscle mass loss*** may be seen in critical illness with low protein intakes. This may result in poor clinical outcomes, especially in malnourished children with low lean body stores
- Critical illness → protein catabolism + malnutrition = **Tragedy**
- ***Both energy and protein intakes need to be optimal to achieve a positive protein balance.***

The inadequacy of protein intake in PICUs has been shown in multiple reports

Several factors contribute to ***inadequate nutrition therapy*** and cumulative energy and protein deficit, such as delayed initiation of NT after admission, multiple or prolonged interruptions, lack of routine nutrition assessment, knowledge gaps and myths surrounding the role of nutrition in the PICU, absence of a uniform NT algorithm, and the use of inaccurate methods for estimation of nutrients and energy requirements

Critically ill infants and children have an ***increase*** in metabolic needs and ***lower*** macronutrient stores

The energy requirements for the critically ill child are highly individualized and may vary widely.

- increased delivery of nutrition is linked to ***reduced*** *infection rates, length of hospital stay, and mortality, especially when nutrition protocols are in place*.1,8,13,15,19
- A recent study confirmed that rates for suboptimal nutrition remain high in PICUs

The trajectory of critical illness varies and is a multifactorial

- ***Hypermetabolism leads to changes in micronutrient and macronutrient needs***
- ***Body storage sites, especially muscles, are depleted for energy With muscle wasting, respiratory insufficiency may lead to delayed weaning from mechanical ventilation.***

- ***Gastrointestinal (GI) dysfunction is commonly reported in critically ill patients. The motility of the GI tract diminishes***

translocation

- ***Alterations in the GI tract place the patient at risk for systemic infections [Malnourished patients](#) often have prolonged hospitalizations and increased hospital costs.***

Poor nutrition status accompanies many chronic childhood diseases. Conditions such as congenital heart disease (CHD), oncologic disorders, significant neurologic dysfunction, and other common chronic conditions contribute to the risk of ***undernutrition***.

Patients with CHD have a 3.6 times higher chance of not reaching satisfactory caloric intake when matched against subjects without CHD.

Factors leading to energy deficiency in children with cancer include insufficient intake, increased metabolic rate, altered physical activity, and inflammation.

Those children with conditions that include **severe motor disability** are at higher risk of **undernutrition.**

Although
the metabolic response in critical illness is
unavoidable
provision of adequate calories
and protein based on
patient size and ***metabolic needs***
is crucial.

DETERMINING NUTRITIONAL NEEDS

- ***A thorough assessment of the critically ill child is required to inform the plan for nutritional support***
The American Society of Parenteral and Enteral Nutrition (ASPEN) nutritional support guidelines for critically ill children recommend that children undergo ***nutrition screening*** to identify those with existing malnutrition and those nutritionally at risk. ***Clinical and biochemical assessment*** strategies provide specific information to support nutritional prescription.

The first step in nutritional risk assessment is a careful ***history***. Accurate and clinically **relevant** nutritional assessment provides important guidance.

Historical growth data, hospitalizations, surgical procedures, and acute and chronic conditions, especially those that have GI sequelae and feeding difficulties, are important to note.

Because of their effect on intake, identifying fine motor dysfunction and chewing and swallowing difficulties is important.

In addition, any recent weight loss or decreases in nutrient intake are key indicators of nutrition risk.

For any hospitalized child, growth assessment is ***vitally important***. Documenting baseline nutrition parameters ***provides guidance for nutrition support***. Body weight, length/height, and body mass index are ***staples of a nutrition assessment strategy***.

Weight loss is the best single physical examination predictor of malnutrition risk.

With children at risk, additional anthropometrics are warranted. In many institutions, registered dieticians measure and compute arm circumference, arm muscle area, arm muscle circumference, and triceps skin-fold thickness. These measurements can provide additional information related to body composition, ***including fat and protein stores***. A reduction in midarm circumference is **linked to negative nitrogen balance**.

Biochemical markers such as ***albumin and prealbumin are commonly used to reflect visceral serum protein***. Albumin has a half-life of 14 to 20 days. Given its long half-life, albumin’s clinical limitations ***make it an imperfect*** marker for evaluating the nutrition status of the critically ill child. ***Prealbumin*** is a stable circulating glycoprotein synthesized in the liver, and has been ***used successfully as an indicator of protein status.***

Prealbumin has a half-life of approximately 24 to 48 hours and correlates with nitrogen balance.

Measurement of energy expenditure has the ability to influence nutritional prescription. Analysis of inspiratory and expiratory gas concentrations to determine oxygen consumption and carbon dioxide (CO_2) production provides an evaluation of intracellular metabolism. According to the ASPEN clinical guidelines, "***energy expenditure should be assessed throughout the course of illness to determine energy needs of critically ill children***." These guidelines support the use of indirect calorimetry, given that standard formulas are ***erratic in their ability*** to match measured energy expenditure. In many institutions, indirect calorimetry is used at the to quantify energy expenditure and drive estimates of caloric needs. Unfortunately, accessibility of necessary equipment and staff with appropriate expertise in the use of indirect calorimetry is unavailable in many PICUs.

Energy Needs

- The energy requirements of a critically ill child ***are highly individualized*** and may vary widely. ***Because the child's metabolism dictates energy needs***, **whatever** changes metabolic response affects the child's need for and use of nutrients.
- ***unlike adults, infants and children have caloric needs for growth***.

- For sick infants and children, “factors” are often used to quantify the impact that stress and activity (or inactivity) have on a child’s energy needs. REE can be multiplied by a factor of **1.5 to 1.6** for a moderately stressed critically ill child with sepsis or acute respiratory failure. A factor of 1.0 or 1.2 is generally sufficient for a ventilated patient with no growth failure. Stress factors higher than 2 are typically reserved for children with burns.

- ***Despite the common use of formulas***, ***concordance*** with energy expenditure has not been shown. To prevent inappropriate caloric intake, ***reassessment of the child's nutrition status*** is imperative.
- Although undernutrition is of significant concern in the PICU ***excessive calories*** are also worrisome. Overfeeding occurs when the amount of calories exceeds the calories needed. Unnecessary calories have the potential to increase CO2 production.High carbohydrate intake increases the respiratory quotient and may ***negatively affect the critically ill child's ventilatory status***.

Macronutrient Needs

- Protein, fat, and carbohydrates are the macronutrients that provide the energy to perform all body functions. ***The amount, source, and density of these macronutrients affect nutritional status***. Guidelines for the dosing of nutrients have been offered by several organizations. In the United States, Institutes of Medicine provides current standards. Recommendations are framed within the context of dietary recommended intakes (**DRI**).
These reference values are divided into ***3 levels***. Recommended daily allowances (RDA), are dietary amounts that meet the needs of more than **97%** of the population for age and sex. Adequate intakes (AI) are based a review of **limited data**, and reflect values that meet the **average child's needs** based on age and sex. Upper limit intake (ULI) identifies the maximum amount recommended for a particular nutrient.

- For sick children, ***increasing amounts of protein*** may be needed. Protein catabolism appears to peak at 8 to 14 days after injury. ***Patients with intractable diarrhea, chest tubes with substantial drainage, and large blood loss are especially in need of added dietary protein***. In patients with severe burns, higher dietary protein intake increases outcomes. Oversupply of protein can also be **toxic** and may be detected by an increase in blood urea nitrogen.

- Carbohydrates are especially important to the brain and the nervous system. ***In the well nourished, carbohydrates prevent protein from being used for energy***. ***Carbohydrates supply nearly half the total caloric intake***. ***Although carbohydrates are an essential component of the diet, early aggressive high glucose concentrations may be detrimental to patients under critical care***

- Fat is essential for cell adhesiveness and, therefore, skin integrity and wound healing. Fat also contributes to the immune system and brain growth. Growth can be maintained with more than 21% of diet from fat. ***Otherwise, diet percentages are recommended for children (1–3 years old: 30%–40% of diet; 4–18 years old: 25%–35%)***

Electrolyte and Micronutrient Needs

- The provision of the correct balance of electrolytes, vitamins, minerals, and trace elements is essential in mitigating nutrition-related consequences. Micronutrients are critical to ***optimizing*** protein, fat, and carbohydrate utilization.

*For the critically ill child, if **deficiencies** exist supplementation is necessary. Although the **ideal** dose of micronutrients for sick children is unknown, a diet that includes required electrolytes and maximizes micronutrients to meet physiologic needs will **promote recovery***

ENTERAL NUTRITION

- Enteral nutrition (EN) is **the most common method** of nutrition delivery in the PICU and is the recommended route of intake. Enteral nutrition is associated with fewer clinical complications and alleviates a variety of nutrition-related concerns.

With EN the risk of translocation of the GI flora is limited, and intestinal integrity is preserved, preventing atrophy of the GI tract.

GALT

Commercial Enteral Formulas

When necessary, a commercial formula is selected based on the child’s needs.

The guiding principle in

formula choice

is usually

composition of protein

Adult formulations are considered safe for most children older than 10 years

Fiber

- Fiber also has a place in the enteral feeding plan. Pediatric formulas including fiber may benefit critically ill children with ***diarrhea, constipation, neuromuscular disease, and immobility.*** By reducing diarrhea, the child holds a better chance for nutrient absorption. Fiber-enriched formulas are also commonly considered for patients receiving **long-term enteral feeding**. For patients at risk of bowel ischemia and severe dysmotility, fiber should be **avoided.**

Timing

For the average ICU patient, nutritional deficiencies build up over the first week of hospitalization. Infants are ***especially*** vulnerable because of their **reduced energy stores**

Although brief nutritional inadequacies may have limited consequences, ***if adequate oral intake is not expected within 24 to 48 hours*** of admission, ***alternative methods*** should be sought.

In addition, early feeding mitigates the breakdown of glycogen and fat stores, and **reduces the inflammatory response**. In a meta-analysis of ***early enteral feedings*** the results suggest an overall treatment effect consistent with a large reduction in mortality and infectious complications. In particular, trauma patients appear to have a decrease in mortality with early feedings

Gaps in Prescription and Delivery

- Achieving the nutrient delivery **goal is a consistent issue** for ICU patients. Children in PICUs **often to not receive satisfactory caloric** intake **despite** the amount prescribed. DeGroof and colleagues noted that only 25% of children with meningococcal sepsis achieved their goal.
- ASPEN acknowledges that barriers exist to adequate EN delivery. Providing nutrition during the early and the most critical stages of illness is often challenged by fluid restriction, operative and procedural interruptions, worries of feeding intolerance, and functional issues such as displaced or clogged feeding tubes.

- *Strategies are needed to identify and prevent avoidable delays in nutrition therapy*. ***A nutrition support team*** and predicable advancement protocols positively affect nutrient delivery in critically ill patients. Gurgieora and colleagues demonstrated that the EN rate **increased** from 25% to 60% with the implementation of a nutrition support team.

- ***Management of residuals varies***, especially in children, and affects interruptions and, therefore, EN delivery. Gastric residual volume (GRV) is not a surrogate for aspiration related to gastric emptying. Although there is no evidence to support the acceptable or unacceptable volume, some suggest that a GRV of 5 mL/kg or 150 mL is significant. With repeated measurement (every 2 hours), EN can be held and monitored for 4 hours and then restarted at 50% of previously fed volume.

Enteral Complications and Limitations

- ***Enteral feeding is not complication free***. Intolerance of EN may be indicated by ileus, abdominal distention, and heme-positive stools. EN is also associated with a risk of nosocomial pneumonia. Although EN is preferred, those who receive EN alone often do not reach energy goals, and underfeeding with EN alone may increase mortality at 60 days.

PARENTERAL NUTRITION

- *Parenteral nutrition (PN) is used in the PICU when the enteral route cannot be used or is unable to provide sufficient nutrients*.
- Conditions such as trauma, sepsis, renal failure, and hepatic failure influence the use and requirements for nutrients. Candidates for PN also include children with intractable vomiting/diarrhea, paralytic ileus, severe short bowel syndrome, and cystic fibrosis, and children following bowel resection. Many of these children have a dysfunctional GI tract and are unable to absorb nutrients, requiring a higher caloric intake than EN can provide.

Before beginning PN, caloric needs are estimated and daily fluid requirements are
calculated based on patient attributes. Although standard commercial preparations are available, PN is often tailored to the critically ill child’s nutritional
needs and metabolic status. PN typically requires 5% to 10% fewer calories than
enteral requirements because of the thermic effect of food absorption.

SUMMARY

A child's added energy requirements and lower macronutrient stores combined with the stress of illness make the critically ill infant and child less able to withstand nutritional deprivation.

Conventional nutrition for critically ill infants and children requires a **diet specific** to their needs with a mix of macronutrients.

Prior nutrition status and severity of the current illness assist in determining the initiation of nutritional support.

Clinical response to feeding is the best indicator of nutritional adequacy.

The potential effect of undernutrition on an already compromised child must lead the health care
team to ensure the child’s nutritional needs are addressed early in their PICU stay.

بـا تـشکر

Enteral Nutrition Delivery

- Delivery of enteral feedings can be accomplished by an intermittent or continuous method. Intermittent feedings mimic normal eating patterns and allow the gut to rest.
- Starting with a small volume of full-strength formula is typically the most appropriate approach.Subsequent increases in volume should be based on patient tolerance. Diluting formula contributes to the delay in reaching nutritional goals, and should be avoided
- The debate over the best EN delivery route persists. The route chosen depends on GI function, the expected duration of tube feeding, and the child's potential for aspiration. Feeding the child via the stomach allows gastric acid and other hormones to respond normally in the digestive process.
- a lower incidence of dumping syndrome. Additional advantages of the gastric route include ease of tube placement and decreased cost.

Because of the theoretical advantages, transpyloric tubes are often preferred for feeding the critically ill infant and child. Transpyloric feedings reduce interruptions and volume of gastric residuals. Postpyloric feedings may also supply more calories compared
with gastric feedings. To some clinicians postpyloric enteral tube placement supports the value and safety of early nutrition, and is recommended when gastric feedings fail. A recent meta-analysis by a Chinese medical team yielded 15 randomized
clinical trials that examined postpyloric versus gastric feeding, and found a reduction in pneumonia with postpyloric feeding. The risk of aspiration and vomiting, however, were not significantly different between patients treated with gastric and postpyloric feeding.

Other pediatric studies have demonstrated no efficacy in the use of postpyloric feeding in comparison with gastric feeding. In addition to aspiration,
gastroesophageal reflux has been noted in children with transpyloric tubes, especially
during periods of feeding. No difference in feeding tolerance, growth and development, and feeding-related complications were noted in transpyloric and gastric feedings for premature infants.[81] In addition, no difference in the incidence of diarrhea,
vomiting, and GI motility has been observed between transpyloric and gastric feedings. For these reasons, ASPEN does not recommend a site of delivery of EN.

Although there is agreement that initiation of PN is initiated in a step-by-step process, there continues to be a debate about when to start PN.

ASPEN recommends

PN after 7 days of hospitalization for the adult patient who is of normal nutrition status,

whereas the European Society for Clinical Metabolism and Nutrition recommend 24 to 48 hours if normal nutrition cannot be obtained in 2 to 3 days.

Mascarenhas and Wallace[98] recommend starting PN if the patient is nil by mouth (NPO) for more than 3 days for the malnourished child, and in the well-nourished child if NPO longer than 5 days. For the trauma patient it may be necessary to begin feeding within the first 3 days from injury. Most experts concur that patients with short lengths of stay, especially when they demonstrate adequate growth and development, should not be prioritized for PN

The amount of protein in PN is calculated by using body weight and multiplying by estimated protein needs for age and condition. In pediatric patients with bronchiolitis, those given 3.1 g/kg/d demonstrated a positive protein balance whereas those receiving 1.7 g/k/d did not.[67] There may be greater protein needs for sick patients who have sepsis, protein-losing enteropathy, and malnutrition. Higher protein amounts improve survival in pediatric burns patients.[6]

The remaining calories in PN are divided between carbohydrates and fat.[98] Targeting carbohydrate calories to 50% to 60% is common, with dextrose providing 3.4 cal/mL.

The concentration of dextrose should be prescribed while keeping in mind the need to avoid hyperglycemia and hypercapnia. Standard lipid administration as part of a parenteral diet recommends 25% to 35% fat

The addition of lipids to meet energy targets decreases the amount of glucose infused, thereby reducing the risk of hyperglycemia and use of insulin to normalize serum glucose

In the United States, Intralipids contain only LCT. These standard fat emulsions contain linoleic acid with omega-6 fatty acids dominating the concentration of omega-3 fatty acids. Omega-6 fatty acid is a precursor of proinflammatory prostaglandins and thromboxanes, and should be infused at controlled rates. In Europe several formulations are available with both MCT and LCT.

Fat emulsions are provided in a 20% solution (2.2 kcal/L). An initial rate of 1 g/kg/d is safe. Advancement can be safely done by monitoring triglycerides. Maximum lipid dose is 3 g/kg/d. If the triglycerides level is higher than 400, one should consider halving the lipid dose

The pediatric multivitamin solution added to PN includes vitamin K, lower amounts
of B vitamins, and larger amounts of vitamin D. The adult formulation for children older
than 11 years contains appropriate levels of calcium and phosphorus for age, and no
208 Verger
vitamin K. PN routinely includes zinc, iron, copper, chromium, manganese, and selenium. For those with liver disease the amount of copper can be decreased to 50%, whereas an increase in copper is recommended for those children with burns.[98]
Decreasing manganese in those patients with hepatobiliary disease has also been recommended.

The peripheral route can be used for children with normal fluid requirements and an expected need for calories for no longer than 1 week. Glucose concentration limits peripheral administration, and an osmolarity of less than 1000 osmol/L is recommended.[98] An increase in the child's basic fluids may be necessary to achieve good distribution of macronutrients.

While on PN, robust laboratory monitoring should occur. It is recommended always
to check electrolytes to obtain a baseline measurement before starting PN. Initially
electrolytes as well as calcium, magnesium, and phosphorus should be checked daily
and then liberalized as patient status and PN stability is achieved. Adjustments in PN
can then be made based on routine analysis of serum levels.

PN differs from EN in safety and efficacy. Overfeeding and a prolonged hypercaloric state are of particular concern with PN because of the ease of adding calories to these artificial solutions.

A 2012 investigation noted that PN was associated with a higher mortality in PICU patients. In addition, a recent multisite clinical trial of adult patients found that PN started at less than 48 hours from admission (rather than after day 8 of admission) resulted in more infectious complications and a prolonged length of stay

Kutsogiannis and colleagues[101] found that use of PN was associated with patients experiencing ARDS and those who had longer lengths of hospital stay before admission to the ICU. Metabolic complications, such as hyperglycemia, and technical issues involving catheter displacement and breakage can also occur with PN. Sepsis risk seems to be a continuing issue despite some investigators questioning study methodology, and speculation that the relationship to infection may be that of hyperglycemia and lack of protein rather than PN.[67] Nonetheless, when PN is optimized to an adequate delivery of calories a neutral caloric balance results, and achieves a dramatic effect on mortality and morbidity.