Learning Objectives:

- To present specific features of children in respect to nutritional requirements and nutrition support;
- To discuss nutritional interventions in paediatric patients;
- To define indications for EN and contraindications to EN in children;
- To describe nutrient composition of various enteral formulas;
- To define standard and disease specific enteral formulations for children and to discuss evidence for their use;
- To discuss principles of feed administration in respect to sites, routes and modes of EN delivery;
- To describe how to initiate and how to wean the patient from EN;
- To discuss the most common complications and to provide recommendations for their prevention;
- To discuss issues of enteral versus parenteral nutrition;
- To present benefits and principles of home enteral feeding.

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Key Messages:

- Enteral nutrition is a safe and effective method of nutritional therapy in paediatric patients.
- Enteral nutrition should be introduced in a child with a functioning gut, whose energy and nutrient requirements cannot be met by a regular food intake.
- Enteral formulas differ substantially in their nutrient content and physical properties; selection depends on the age and clinical condition, but for the majority of paediatric patients a standard polymeric enteral formula is an appropriate choice, with the best cost-benefit ratio.
- Intragastric feeding is the preferred method of enteral feed delivery as it is associated with higher tolerance and fewer complications.
- Technical, metabolic, gastrointestinal, infective and psychological complications may occur during enteral nutrition, and therefore, close monitoring and strict adherence to the established protocols are of crucial importance.
- The main advantages of enteral over parenteral nutrition include preservation of gastrointestinal function, cost, manageability, and safety.

1. Basic Principles of Enteral Nutrition (EN) in Children

1.1. Specific features of paediatric age in respect to nutritional requirements and nutrition support

Children represent a nutritionally vulnerable population requiring a number of special considerations:
- Nutritional requirements per unit of body weight are much higher than in adults due to:
  - growth and organ maturation
  - increased losses (large surface area to body mass ratio)
  - limited body reserves.
- Consequences of inappropriate nutrition are more pronounced and may influence long term health, particularly if expressed during critical periods of rapid growth and maturation – this applies for physical as well as for mental/cognitive development, and in developing risk factors for various chronic disorders.
- Infancy and early childhood are periods when attitudes and skills to different tastes and textures are acquired. Bypassing oral intake or prolonged formula feeding may therefore adversely affect taste and oral motor function development.
- In the paediatric age group, dietetic/nutritional therapy is often a treatment of choice for different disorders such as congenital metabolic disorders, food allergy, and several chronic gastrointestinal diseases such as chronic diarrhoea of infancy, short gut syndrome, Crohn’s Disease, etc.

Therefore, the goal of nutritional support in paediatric patients is to provide appropriate amounts of energy and other nutrients to support optimal growth and development, while preserving body composition, minimizing gastrointestinal symptoms and promoting developmentally appropriate feeding habits and skills. Also, nutritional therapy should aim to prevent malnutrition rather than being delayed until children have already been exposed to its immediate and long term adverse effects.
1.2. Nutritional interventions in children

The most appropriate nutritional interventions in children will be determined by the child's age, clinical condition, gastrointestinal function (digestion and absorption), possibilities for oral intake, as well as by dietary habits and costs (1). Following assessment of the above, paediatric patients may receive:

- intensified nutritional counselling on the type and quantity of the preferable food intake;
- oral nutritional supplements;
- different enteral feeding regimes;
- parenteral nutrition with or without oral or enteral intake.

In principle, the intensity of the approach used will increase in a stepwise manner along with the severity of the disorder (2).

1.3. Definition of EN

Enteral nutrition is defined here as delivery of liquid formula beyond the oesophagus via a feeding tube / stoma, and also, as oral provision of dietary foods for special medical purposes as defined in the European legal regulation of the Commission Directive (3).

1.4. Indications and contraindications

In general, enteral nutrition should be introduced in a child with a functioning gut, whose energy and nutrient requirements cannot be met by regular food intake. It is also indicated whenever diet is used as a treatment of the disease (food intolerances, Crohn's disease), and in a disabled child when the feeding time is excessively prolonged (> 4–6 hours/day)(1,4). Suggested criteria for nutritional support are presented in Table 1. In some clinical settings such as intensive care units, reliance on EN alone may result in severe underfeeding despite a functional gut, mostly due to fluid restriction, inadequate prescription and/or delivery (5). In those patients a combination of EN and PN is recommended (1).

<table>
<thead>
<tr>
<th>Table 1. Suggested criteria for nutrition support (adapted from 1, 4)</th>
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<tbody>
<tr>
<td><strong>Insufficient oral intake</strong></td>
</tr>
<tr>
<td>Inability to meet 60% to 80% of individual requirements for &gt;10 days</td>
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<tr>
<td>Total feeding time in a disabled child &gt; 4 to 6 hours/day</td>
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<tr>
<td><strong>Wasting and stunting</strong></td>
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<tr>
<td>Inadequate growth or weight gain for &gt;1month in a child younger than 2 y</td>
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<tr>
<td>Weight loss or no weight gain for a period of &gt;3months in a child older than 2y</td>
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<tr>
<td>Change in weight for age over 2 growth channels on the growth charts</td>
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<tr>
<td>Triceps skinfolds consistently &lt;5th percentile for age</td>
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<tr>
<td>Fall in height velocity &gt;0.3 SD/y</td>
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<tr>
<td>Decrease in height velocity &gt;2 cm/y from the preceding year during early/mid puberty</td>
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<tr>
<td><strong>Treatment of the disease</strong></td>
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<tr>
<td>Metabolic diseases (e.g. galactosaemia, hereditary fructose intolerance, primary lactose intolerance)</td>
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<tr>
<td>Food allergy (in infants: e.g. cow's milk protein sensitive enteropathy, multiple food allergy)</td>
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<tr>
<td>Crohn's disease</td>
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Clinical indications for EN are listed in Table 2.
Table 2. Clinical indications for paediatric enteral nutrition (adapted from 6)

<table>
<thead>
<tr>
<th>1. Inadequate oral intake</th>
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<tbody>
<tr>
<td>Disorders of sucking and swallowing</td>
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<tr>
<td>- Prematurity</td>
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<tr>
<td>- Neurologic impairment (eg. cerebral palsy, dysphagia)</td>
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<tr>
<td>Congenital abnormalities of the upper gastrointestinal tract</td>
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<tr>
<td>- Tracheoesophageal fistula</td>
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<td>Tumours</td>
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<tr>
<td>- Oral cancer</td>
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<td>- Head and neck cancer</td>
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<tr>
<td>Trauma and extensive facial burns</td>
<td></td>
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<tr>
<td>Critical illness</td>
<td></td>
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<tr>
<td>- Mechanical ventilation</td>
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<tr>
<td>Severe gastro-oesophageal reflux</td>
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<tr>
<td>Food aversion</td>
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<td>Anorexia and depression</td>
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<tr>
<th>2. Disorders of digestion and absorption</th>
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<tbody>
<tr>
<td>Cystic fibrosis</td>
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<tr>
<td>Short bowel syndrome</td>
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<tr>
<td>Inflammatory bowel disease</td>
<td></td>
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<tr>
<td>Malabsorption syndrome due to food allergy</td>
<td></td>
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<tr>
<td>- Cow's milk protein</td>
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<tr>
<td>- Multiple food</td>
<td></td>
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<tr>
<td>Enteritis due to chronic infection</td>
<td></td>
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<tr>
<td>- Giardia lamblia</td>
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<tr>
<td>Protracted diarrhoea of infancy</td>
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<tr>
<td>Intractable diarrhoea of infancy</td>
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<tr>
<td>Severe primary or acquired immunodeficiency</td>
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<tr>
<td>Chronic liver disease</td>
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<td>Graft versus host disease</td>
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<td>Intestinal fistulae</td>
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<th>3. Disorders of gastrointestinal motility</th>
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<tr>
<td>Chronic pseudo–obstruction</td>
<td></td>
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<tr>
<td>Extensive ileocolonic Hirschsprung's disease</td>
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<th>4. Increased nutritional requirements &amp; losses</th>
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<tbody>
<tr>
<td>Cystic fibrosis</td>
<td></td>
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<tr>
<td>Chronic solid organ diseases: renal, heart, liver</td>
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<tr>
<td>Inflammatory bowel disease (Crohn’s disease, ulcerative colitis)</td>
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<tr>
<td>Multiple trauma, extensive burns</td>
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<th>5. Growth failure or chronic malnutrition (in addition to above)</th>
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<tbody>
<tr>
<td>Anorexia nervosa</td>
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<tr>
<td>Non-organic failure, Food deprivation</td>
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<th>6. Crohn's Disease: primary disease treatment</th>
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<tr>
<th>7. Metabolic diseases</th>
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The absolute contraindications to EN are: necrotizing enterocolitis and intestinal perforation, GI tract obstruction, mechanical and paralytic ileus, and intestinal atresia.
The relative contraindications are intestinal dysmotility, toxic megacolon, severe GI bleeding, high-output enteric fistula, unexplained severe vomiting and intractable diarrhoea, and inability to access the gut (severe burns, multiple trauma).

### 2. Nutrient Composition of Enteral Formulas

#### 2.1. Carbohydrates

Carbohydrates in enteral formulas are sourced from different starches, including corn and tapioca. Maltodextrin and hydrolyzed cornstarch, glucose-derived saccharides, and corn syrup are the most commonly used (6). Concerning lactose, the majority of paediatric enteral formulae do not contain lactose or it is present in trace/limited amounts. The optimal amount of carbohydrate in enteral formulas is unknown, but most available standard paediatric enteral formulae contain 40 – 55 % of carbohydrates.

#### 2.2. Proteins

Most enteral formulae are casein, whey or soy protein based. Protein content is mostly around 10%, but may vary between 10%-20%. The nitrogen to non-nitrogen calorie ratio is approximately 1 to 150 (6).

#### 2.3. Lipids

In enteral nutrition, lipids are administered predominantly as triglycerides – either as long-chain fatty acid triglycerides (LCT) or medium-chain fatty acid triglycerides (MCT). MCT, derived mostly from coconut oil, is rapidly hydrolysed and effectively absorbed into the portal circulation, even at low concentrations of pancreatic enzymes and in the absence of bile acids. However, the energy content per unit of MCT is some 14% lower than that of LCT, a high intake may promote osmotic diarrhoea, and it contains no essential fatty acids (EFA). Therefore, most of the MCT-based enteral formulae include up to 50% of EFA rich LCT. LCT promotes intestinal motility and stimulates biliary and pancreatic secretions. However, an excess of LCT in the intestinal lumen, especially if it is hydroxylated by bacteria, reverses water and electrolyte absorption and causes net secretion, thereby worsening malabsorption. Total lipid intake should be 3–4 g·kg^−1·day^−1, depending on age, absorptive capacity and digestive tolerance (2).

#### 2.4. fibre

Enteral formulae were originally designed to have a low fibre or residue content. However, fibre has been found beneficial in constipated patients, and serves as a substrate for bacterial production of short-chain fatty acids. Short-chain fatty acids, particularly butyrate, are considered to be trophic for large bowel mucosa as they are preferentially used as an energy source for colonocytes. It is, therefore, currently recommended to use a mixture of bulking and fermentable fibre (1). This has been substantiated with the result of meta-analysis of controlled studies in adults and in children that compared fibre-supplemented with fibre-free formulations provided as the sole source of nutrition. This showed a significant benefit on bowel functioning, both in patients and in healthy subjects, irrespective of whether the predominant symptom in the former was diarrhoea or constipation (7).
2.5. Micronutrients

Due to growth and organ maturation children have increased requirements for vitamins and trace elements, and the Recommended Dietary Allowances, therefore, depend on the age of the patient (1,2). Although the amount of micronutrients varies among different dietetic products, most paediatric enteral formulae contain sufficient micronutrients to meet increased needs associated with stress and wound healing provided that the recommended daily dose of feed is delivered.

2.6. Nutrient Density and Osmolarity

The nutrient density of enteral feeding is a function of its fluid content. At standard dilution, the caloric content of infant formula is usually 0.67 kcal/ml, and that of standard paediatric enteral formulae equals 1 kcal/ml (3). More concentrated enteral formulas are also available (1.3-2.0 kcal/ml) for patients with increased energy requirements or with limited fluid intake.

Osmolality refers to the concentration of osmotically-active particles per litre of a liquid formula, expressed as mOsm/L. The osmolality is affected by the concentration of all constituents such as amino acids, carbohydrates, lipids, and electrolytes. Formulae with higher osmolality than normal body fluids produce an osmotic effect on the intestinal wall, drawing water into the lumen. An influx of water may result, therefore, in diarrhoea, nausea, cramping, and abdominal distension (9). This is particularly important in children with severe small intestinal disease, or when EN is delivered directly into the jejunum. In those patients, isotonic formulas of approximately 300 mOsm/L, are preferred.

3. Enteral Formula Selection

Enteral formulae should supply a balanced intake of energy and other nutrients to support age appropriate growth and development. The content of all essential nutrients should provide at least 100% of the reference intake for healthy individuals of the relevant age group, related to the usual energy supply for that group (1). To make an appropriate selection of an enteral formula, the following factors should be considered:

• nutrient composition and energy should be age adapted and only after the age of 8 to 10 years can an adult formulation be used, in the event that the appropriate paediatric formula is not available;
• history of food intolerance or allergy;
• intestinal functions in respect to digestion and absorption;
• site and route of delivery;
• formula characteristics such as osmolality, viscosity, nutrient content;
• taste preference;
• cost.

3.1. Standard paediatric enteral formula

The standard paediatric enteral formula has an energy density of 1 kcal/ml, iso-osmolarity (300-350 mOsm/kg), whole proteins as its nitrogen source (polymeric formula), and content adapted to the requirements of children from 2 to 10 years of age. In addition, it is generally lactose and gluten free, and should now also contain fibre. Standard paediatric polymeric enteral formulae are sufficient and well tolerated by the great majority of paediatric patients requiring EN, with the best cost-benefit ratio.
3.2. Disease specific enteral formulae

Besides standard enteral formulations, there are many specialized and disease-specific enteral formulas. They were firstly developed for infants and children with intolerances such as food allergy or inborn errors of metabolism, who required elimination of one or more food components. Their benefits were easily recognized and their use positioned with recommendations such as guidelines for treatment of food allergy (10). The next steps in EN formulation were different modifications aiming for benefit for specific disorders. The examples are formulations tailored to meet the specific requirements of patients with altered intestinal absorptive capacity, insufficient pancreatic, hepatic or renal function, with increased energy and protein requirements, and with pulmonary failure. The most recent research topics in the design of enteral formulae include addition of anti-inflammatory cytokines or nutrients which, if provided in high doses, could exert immunoregulating effect, and are therefore named pharmaconutrients. Transforming growth factor-β enriched formulae for exclusive EN therapy of active Crohn's disease, and glutamine enriched formulae for improving gut barrier function and decreasing mucositis in paediatric oncology patients (11) and in preterm infants (12), are examples of pharmaconutrients dedicated to disease treatment. However, despite the fact that those modifications are in line with the pathophysiology of the diseases, clinical benefits remain questionable (1). There are very few controlled studies in paediatric patients, and for that reason claims of benefits should be evaluated critically (13).

3.3. Formula selection in respect of nitrogen origin: polymeric vs oligomeric vs elemental

Polymeric formulas contain macronutrients in the form of intact protein, triglycerides and carbohydrate polymers. These formulas are in general terms nutritionally complete, iso-osmolar and cheap, and are therefore the most frequent choice, both in hospital and in home settings. Most of them are also lactose–free and gluten–free. Since these preparations are palatable, they may be used for oral / bolus feeding, as well as for tube feedings (14). Chemically defined oligomeric enteral formulas contain macronutrients that are pre-digested, thus requiring minimal digestion and being almost completely absorbed in the upper jejunum. Most importantly, proteins are hydrolysed to a degree that most of the epitopes are destroyed, and the feeds are therefore called hypoallergenic. By definition, hypoallergenic formulas are tolerated by at least 90% of children, mostly infants, with already established cow's milk protein allergy (15). Up to 10% of patients have multiple food allergies and require an elemental formula (10,16). Commercially available semi-elemental formulas containing protein hydrolysate and MCT can be safely used in children with GI disease, but their use is more costly and should be limited to specific indications. As they are hyperosmolar, the total daily volume as well as the concentration should be increased more cautiously.

Monomeric/elemental formulas are nutritionally complete mixtures containing their nitrogen source in the form of amino acids, carbohydrates as oligosaccharides, and fats as a mixture of LCT and MCT. They are often used in patients with severe multiple food allergy non-responsive to oligomeric formulas (16), and in patients with severely impaired digestion and absorption. With the exception of infant elemental formulae, their osmolality is usually high (500–900 mOsmol/l) and they may, therefore, cause osmotic diarrhea, particularly if delivered directly into the jejunum in the form of a bolus or by too rapid infusion. The unpalatability and high osmotic load limit the use of elemental formulae to tube feeding of patients with specific clinical indications (e.g. severe malabsorption, extremely short gut syndrome, infants with severe multiple food allergy) (14). A comparison of polymeric,
oligomeric and monomeric formulas, concerning energy, macronutrient content, and osmolarity, is presented in **Fig. 1.**

<table>
<thead>
<tr>
<th></th>
<th>Polymeric formulas</th>
<th>Oligomeric formulas</th>
<th>Monomeric formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protein content</strong></td>
<td>30-80 g/L</td>
<td>20-50 g/L</td>
<td>19.5 - 25 g/L</td>
</tr>
<tr>
<td><strong>Caloric density</strong></td>
<td>1-2 kcal/mL</td>
<td>1-1.7 kcal/mL</td>
<td>0.67 - 1 kcal/mL</td>
</tr>
<tr>
<td><strong>Carbohydrate content</strong></td>
<td>90 -200 g/L</td>
<td>100-200 g/L</td>
<td>81 - 146 g/L</td>
</tr>
<tr>
<td><strong>Fat content</strong></td>
<td>20-90 g/L</td>
<td>5-20 g/L</td>
<td>35 g/L</td>
</tr>
<tr>
<td><strong>Osmolarity</strong></td>
<td>300 mOsmol/L</td>
<td>300-600 mOsmol/L</td>
<td>300 - 600 mOsm/L</td>
</tr>
</tbody>
</table>

**Fig.1.** Energy, macronutrient content and osmolarity of polymeric, oligomeric and monomeric formulas

### 3.4. Modular Feeds

Most of the above mentioned formulae are nutritionally complete and commercially prepared. However, EN can be prepared in a hospital kitchen by a dietician mixing separate, commercially available nutritional solutions which contain only one or two of the major nutrients. In this way, nutrients are added separately, and are tailored to meet the specific requirements of an individual child. Modular feeding allows variation in the ratio of nutrients without affecting the quantity of other substances. Special indications include: specific organ dysfunctions (renal, liver, cardiac), metabolic errors, fluid restriction, diabetes mellitus, respiratory and cardiac failure and major electrolyte disorders (14).

### 4. Administration of EN

#### 4.1. Sites of Delivery

EN can be administrated either into the stomach or into the proximal small intestine, depending on: a) morphological and functional status of the gut; b) expected duration of EN; c) anticipated risk of aspiration. **Intragastric feeding** is the preferred method as:

- it stimulates physiologic digestive and hormonal responses;
- it retains antimicrobial function of gastric juice;
- hyperosmolar solutions are better tolerated;
- tubes are more easily placed and maintained;
- the stomach serves as a reservoir gradually releasing nutrients into the small bowel.
Therefore, intragastric feeding is associated with more flexible feeding schedules, larger volume and higher osmotic tolerance, lower frequency of diarrhoea and of dumping syndrome. However, if there is a high risk for aspiration such as in patients with gastroparesis, severe gastro-oesophageal reflux or gastric outlet obstruction, intrajejunal feeding is the preferred route. Although often preferred in small preterm babies, a recent meta-analysis has not confirmed that transpyloric feeding in preterm babies is associated with either a lower rate of complications or with better growth compared to intragastric nutrient delivery. Moreover, an increased incidence of gastrointestinal disturbances and of mortality was found in the postpylorically fed group (17). Despite a lower risk of gastro-oesophageal reflux, studies have shown that reflux occurs also during transpyloric feedings and that the rate of reflux episodes is doubled during feeding compared to non-feeding periods (18).

4.2. Routes of Delivery

If the expected duration of EN is short (< 6-12 weeks), EN is preferentially delivered by nasogastric or nasoenteric feeding tube. In cases when the expected duration is > 6–12 weeks, a feeding gastrostomy or jejunostomy is recommended. Gastrostomies and jejunostomies can be placed:

- surgically;
- endoscopically;
- radiologically.

Endoscopic placement is the quickest and the cheapest procedure with a low rate of complications. However, in neurologically severely impaired children an operatively placed gastrostomy combined with Nissen fundoplication is the procedure of choice. Radiological procedures expose children to ionizing radiation and are more expensive than endoscopy (4). Detailed guidelines on the role of endoscopy in enteral nutrition provision are provided elsewhere (19-22). As reviewed in the ESPGHAN Comment on EN in children (1), NG tube feeding has a higher rate of discomfort and complications (irritations, ulcerations, bleeding, displacement, clogging) when compared to gastrostomy feeding. Gastrostomy feeding is also superior with regard to nutritional efficacy and acceptability, thus improving the quality of life (1). In the same guidelines, antibiotic prophylaxis before PEG placement with intravenous cephalosporins was recommended as it may reduce the prevalence of wound infection. Resumption of feeding could be initiated already within the first 6 hours after PEG placement in children, first with electrolyte or glucose solution, while full enteral feeds can be provided 24 hours after PEG placement (1).

The most common route for delivering EN in children, irrespective of their age, is via a nasogastric (NG) feeding tube made from polyvinyl chloride (PVC), polyurethane or silicon. The first option is the least desirable because PVC tubes can release potentially toxic phthalate esters into lipid-containing feeds, and if left in place for > 5 days become rigid and may cause lesions of the upper GI tract. PVC tubes require frequent replacement (3-5 days); fine-bore tubes (silicon and polyurethane) can be left in place for up to 8 weeks (1).

The diameter of the feeding tube is selected according to the weight and age of the child, with the smallest external diameter being preferred as it causes less patient discomfort. The required length of the tube in children equals the distance from the nose to the ear to the xiphoid, and placement into the stomach is checked by the aspiration of gastric juice confirmed by measuring pH of the aspirate (which should be below 4) (23). In contrast to what was previously recommended, recent studies in neonates determined that pH ≤ 5 is a reliable and safe cut-off for confirmation of intragastric tube placement (24), and the distance nose to ear to mid-umbilicus is more precise than nose-ear-xiphoid for predicting the insertion length for gastric placement in neonates (25). Radiologic confirmation must be obtained when:
• pH is >5;
• an aspirate cannot be obtained;
• patient’s condition changes during NG tube insertion with prolonged coughing, restlessness or severe discomfort or hoarseness (23).

4.3. Modes of Delivery

Modes used to deliver enteral feeding are:
• intermittent
• continuous
• combined

If well tolerated, bolus administration into the stomach is generally preferred as it is more physiological, provides cyclical hormone surges and regular gallbladder emptying, it is cheaper and less restrictive. However, in patients with severely impaired GI function, continuous feeding is beneficial due to:
• lower thermogenic effect thus contributing to enhanced weight gain;
• improved substrate utilization.

A constant infusion of nutrients at a rate below 3 kcal/min\(^1\) is required to avoid exceeding the gastric emptying rate and causing vomiting. The risk of vomiting may also increase if the gastric emptying rate is slowed by increasing the nutrient concentration and/or osmotic load (2). A constant flow can be ensured by the use of a peristaltic enteral pump. When the child can eat, both methods of feed delivery can be combined with tube feeding overnight for 10-12 hours and oral intake during the day. This combination is particularly beneficial for the preservation of sensory and motor oral functions.

4.4. Initiation of EN

Continuous enteral nutrition should be introduced gradually and its rate and concentration increased in a stepwise manner depending on:
• age;
• clinical condition of the patient, particularly the functional and morphological state of the gut;
• formula choice, i.e. polymeric versus elemental;
• route of delivery, i.e. stomach versus small intestine.

Slow introduction is particularly important for patients with chronic intestinal failure, where partial parenteral nutrition may be necessary for many months – sometimes for life or until intestinal transplantation is performed.

Slow increase in feeding volumes is also important in preterm, low birth weight infants to minimize the chance of developing necrotizing enterocolitis (NEC). This practice has been challenged by the Cochrane meta-analysis of rapid versus slow advancement that failed to demonstrate any difference in NEC (26). However, a recently performed randomized prospective trial in preterm infants has shown that infants fed greater volumes developed NEC significantly more frequently (10% vs. 1.4%), while the maturation of intestinal motor patterns, the incidence of late sepsis and feeding intolerances were similar in both feeding groups (27).

4.5. Weaning from EN

Once the child is in a stable condition, and after achieving satisfactory nutritional status, transition from EN, particularly continuous feeding, to normal oral bolus feeds should be considered. In that process the following should be anticipated:
• weaning process consists of increasing oral intake pari passu with decreasing enteral feeding;
• it may take from a few weeks to many months;
• close supervision is required to ensure adequate total nutrient intake, and to avoid cessation of weight and/or height gain;
• EN can be stopped when oral intake satisfies recommended caloric requirements and growth continues to be appropriate to age.
Recent study has shown that the introduction of normal oral bolus feeding is particularly demanding if started after the age of 5 years, not only because the critical time window for development of age appropriate feeding skills is missed, but also because parents are too anxious to agree to commonly seen short-term weight loss (28).

5. Monitoring and Complications

Children receiving enteral nutrition should be monitored regularly for growth, fluid, energy and other nutrient intake, therapeutic efficacy, clinical, haematological and biochemical changes, intolerances and other possible adverse effects. Several groups of complications may occur during enteral nutrition.
• Technical complications during tube and/or stoma placement and maintenance may occur, such as malposition, displacement, migration, blockage. If kept in place for more than 4 – 5 days, PVC NG tubes become rigid and may, therefore, cause GIT bleeding, inflammation or perforation. Strict adherence to protocols and careful supervision of the procedure and of the patient are essential.
• Metabolic complications most commonly comprise fluid, glucose and electrolyte imbalances, re-feeding syndrome and trace element deficiencies. Regular monitoring, dietetic supervision, selection of a formula appropriate to age and clinical condition, avoidance of drip feeding and of blenderized feeds are the best preventative measures. In respect to re-feeding syndrome, children at highest risk are those with severe chronic malnutrition, exposed to rapid introduction of feeding, irrespective of whether it is by the parenteral or enteral route. Intake limited to 50% of the protein and energy requirements, with gradual increase over the next 3-5 days, and preventative supplementation of potassium, phosphate and magnesium, together with water and fat soluble vitamins, is the currently suggested approach (1).
• Gastrointestinal symptoms are the most common complications, including aspiration, diarrhoea, constipation, nausea, and vomiting, bloating, and abdominal distension. These may be minimized by selection of the appropriate enteral formula and mode of delivery, gradual introduction of the feed with monitoring of residual gastric volumes, and anticipation of the patient’s clinical condition. Infective complications can be a consequence of bacterial contamination of the feeding solutions, and may present as gastroenteritis or even with septicaemia. Manipulation at the bedside seems to be critical for bacterial safety (29). Therefore, good hygiene in handling procedures, limited hanging time for decanted feeds, and bacteriological monitoring must follow the established standards and undergo regular quality controls (29). The optimum feed hang time is uncertain and it differs whether the commercially available closed sterile “ready to hang” systems are used, which can be left for 24-36 hours, or if a powdered non-sterile formula is reconstituted with water and poured into the feeding container, in which case the hanging time is limited to 4 hours. Sterile (liquid) formula in an open system can hang for 8 hours in the hospital, and up to 12 hours at home, as defined in the recently published guidelines (30).
• Psychological consequences such oral food aversion and altered body self-image may result from deprivation from the normal oral feeding experience. Training of sucking and swallowing, introduction of non-nutritive sucking (dummy), tasting as many of different foods as allowed, speech therapy and initiation of oral bolus feeds as soon as possible are the most important measures in the prevention of psychological complications.
Fig. 2. Clinical complications of enteral feeding

Despite the broad range of possible complications, EN is a relatively safe and effective way of improving nutritional status, clinical condition and growth of paediatric patients, particularly if procedural protocols are followed, and regular quality control is applied (31).

6. Enteral versus Parenteral Nutrition

Enteral nutrition has a number of potential advantages over parenteral nutrition in the management of patients requiring nutritional support. The main advantages of enteral nutrition include preservation of gastrointestinal function, cost, manageability, and safety.

- **Preservation of gastrointestinal function**
  Apart from the oral phase of digestion, enteral nutrition activates the same gastrointestinal responses as the ingestion of normal meals. The presence of intra-luminal nutrients stimulates (2) gastrointestinal neuroendocrine function, affects motility and digestion through the secretion of digestive juices and gastrointestinal hormones, and (4) maintains gut mucosal mass, including gut-associated lymphoid tissue (GALT).

- **Cost**
  Enteral nutrition is estimated to be two- to fourfold less expensive than parenteral nutrition on an inpatient or outpatient basis (32).

- **Manageability and safety**
  As a result of the advances in tube technology, delivery methods, technical skill of health professionals, and better education of parents and caregivers, the administration of enteral nutrition has been associated with improved clinical outcome and safety profiles (33). Compared to parenteral nutrition, enteral feeding is much easier and safer, and there is also a much wider margin for errors resulting in metabolic complications.

Therefore, it is generally recommended that the enteral route is used whenever the gut is functional, and to use it to the maximally tolerated amount to minimize the need for parenteral intake as much as possible, either in hospital or at home (9).
7. Home Enteral Nutrition

It is well established that home EN is safe and effective, and though this is difficult to assess, children seem to be more active and happier at home. Home EN must be considered whenever the clinical condition of the patient is stable and well controlled. In one paediatric series, the indications for home EN were digestive disorders in 35% of patients, neurological and muscular diseases also in 35%, malignancy in 11%, and failure to thrive in 8% of children (34). The range of indications will probably continue to grow, following the advances in clinical care, and particularly the development of cheaper, safer and more portable enteral pumps and other facilities.

Children on home EN should be followed by a dedicated multidisciplinary team, the importance of which can not be overemphasized (35). A good collaboration with the Primary Health Service in the field is also required. One of the most important roles of the team is teaching parents and/or children the techniques required for EN, before being discharged home, including:

• NG tube placement, NG tube or gastrostomy tube management and maintenance care;
• sterile preparation and appropriate feed storage;
• feeding administration and enteral pump handling and operating;
• monitoring of the child, and the prevention, recognition and management of the most common complications (2).

8. Summary

In this module we discuss various aspects of enteral nutrition in paediatric patients. Indications, contraindications, administration of EN, monitoring and complications are described. Nutrient composition of various enteral formulas is presented and criteria for enteral formula selection are described.

9. References


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