

Practical Approach to Paediatric Enteral Nutrition: A Comment by the ESPGHAN Committee on Nutrition

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ABSTRACT

Enteral nutrition support (ENS) involves both the delivery of nutrients via feeding tubes and the provision of specialised oral nutritional supplements. ENS is indicated in a patient with at least a partially functioning digestive tract when oral intake is inadequate or intake of normal food is inappropriate to meet the patients' needs. The aim of this comment by the Committee on Nutrition of the European Society for Pediatric Gastroenterology, Hepatology, and Nutrition is to provide a clinical practice guide to ENS, based on the available evidence and the clinical expertise of the authors. Statements and recommendations are presented, and future research needs highlighted, with a particular emphasis placed on a practical approach to ENS. Among the wide array of enteral formulations, standard polymeric feeds based on cow's-milk protein with fibre and age adapted for energy and nutrient content are suitable for most paediatric patients. Whenever possible, intragastric is preferred to postpyloric delivery of nutrients, and intermittent feeding is preferred to continuous feeding because it is more physiological. An anticipated duration of enteral nutrition (EN) exceeding 4 to 6 weeks is an indication for gastrostomy or enterostomy. Among the various gastrostomy techniques available, percutaneous endoscopic gastrostomy is currently the first option. In general, both patients and caregivers express satisfaction with this procedure, although it is associated with a number of well-recognised complications. We strongly recommend the development and application

of procedural protocols that include scrupulous attention to hygiene, as well as regular monitoring by a multidisciplinary nutrition support team to minimise the risk of EN-associated complications.

Key Words: complications, enteral nutrition support, formulations, indications, paediatric patients, techniques

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Paediatric patients represent a particularly vulnerable population that has specific nutritional requirements, as highlighted in the position paper by the European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) Committee on Nutrition (CoN) (1). The disease-related consequences of malnutrition, their causal mechanisms, and recommendations for nutritional support teams were thoroughly reviewed (1), with emphasis placed on the importance of providing optimal nutrition to all patients (1–3).

The most appropriate mode of nutritional intervention will be determined by the patient's age, clinical condition, gastrointestinal function (digestive and absorptive), the opportunity for oral intake, and by feasibility, dietary habits, and costs. Following assessment of the above, the patient may receive dietary advice, oral nutritional supplements, a particular enteral feeding regimen, or parenteral nutrition (PN) (4,5).

The aim of this ESPGHAN CoN comment is to provide a clinical practice guide to enteral nutrition support (ENS) in paediatric patients. On the basis of the available evidence and the authors' expertise, paediatric enteral nutrition (EN) techniques are reviewed with emphasis on a practical ("how to") approach. The article also highlights those areas where uncertainties regarding use of EN call for further research.

METHODS

Relevant papers were identified by searching the MEDLINE database (1966–2008) via PubMed, and the Cochrane Database of Systematic Reviews (1988–2008). The reference lists from identified studies and key review articles and guidelines, including previously published guidelines on EN in adults, were also searched. We used the terms *EN*, *tube*, *feeding*, *gastrostomy*, *jejunostomy*, *refeeding*, *indications*, and *complications*, and limited our search to the paediatric population using the additional search terms *infants* or *children* or *adolescents*.

The data were reviewed and written by members of CoN, and all of the authors, including representatives of the ESPGHAN Committee on Gastroenterology, approved the final text.

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DEFINITION OF ENTERAL NUTRITION SUPPORT

ENS traditionally has been regarded as delivery of food beyond the oesophagus via tube, either to the stomach or post-pylorically (6); however, in recent guidelines from the European Society for Parenteral and Enteral Nutrition (ESPEN) (7), the term EN encompasses the use of *dietary foods for special medical purposes* as defined in the European legal regulation of the Commission Directive 1999/21/EC (8), irrespective of the route of delivery.

Recommendation The ESPGHAN CoN supports the definition of ENS embracing both delivery of liquid formulations via tube and provision of specialised oral nutritional supplements.

INDICATIONS FOR ENTERAL NUTRITION

EN is indicated when energy and nutrient requirements cannot be met by regular food intake in a patient with at least a partially functional gut. Also, EN is the option when diet is used as a treatment for the disease (eg, Crohn disease, food intolerance) (9,10).

In the paediatric literature, commonly accepted criteria for nutritional intervention (Table 1) are not evidence based (4,11), and the objectives of EN depend on the clinical condition of the patient (12–14). Specific clinical situations for which paediatric EN may be required are listed in Table 2 (5,11,15–18).

Although evidence comes mainly from adult patients, in children with at least a partially functional gut, EN has the following advantages compared with PN: preservation of gastrointestinal function (19,20); technically more simple, with a better safety profile (21); avoidance of PN-associated complications, such as catheter-related sepsis and liver disease; and a 2- to 4-fold lower cost (22).

In some clinical settings such as paediatric oncology and intensive care units, however, reliance on EN alone may result in an unsatisfactory nutritional outcome, with patients receiving as little as half of their energy requirements due mainly to fluid restriction, inadequate prescription, and/or delivery. The most common causes for failed delivery are clinical instability, airway management, diagnostic procedures, gastrointestinal complications, and the use of drugs (23,24). Therefore, partial PN may be required even in the presence of a functional gastrointestinal tract (25,26).

Recommendation EN is indicated in the patient with at least a partially functional gut and insufficient normal oral intake. To meet nutritional targets in some clinical settings,

combined PN and EN are necessary, even in the presence of a functional gut.

Research Needs Indications/criteria for nutrition support in paediatric patients should be further defined in general and with respect to specific clinical situations.

CONTRAINDICATIONS TO ENTERAL NUTRITION SUPPORT

Contraindications to ENS include paralytic or mechanical ileus, intestinal obstruction, perforation, and necrotising enterocolitis. Conditions considered as relative contraindications include intestinal dysmotility, toxic megacolon, peritonitis, gastrointestinal bleeding, high-output enteric fistula, severe vomiting, and intractable diarrhoea. Under these clinical circumstances, EN should be provided to the maximum extent tolerated by the patient, with PN making up any nutritional deficit. Even minimal quantities of nutrients in the gastrointestinal tract (so-called trophic feeding) may promote intestinal perfusion, initiate release of enteral hormones, and improve gut barrier function (27,28).

Recommendation Complete enteral starvation should be avoided whenever possible.

ENTERAL FORMULATIONS

EN is predominantly offered as liquid ready-to-feed formulations, although some powdered preparations are available that are mixed with water or milk before feeding. Products available for children can be categorised as either “enteral feeds” or “supplemental feeds.” Enteral feeds supply a balanced mix of all of the essential nutrients needed for meeting physiological requirements and growth. Enteral feeds are designed to serve as the sole source of nutrition even during prolonged periods of time. The content of all of the essential nutrients in such formulations should generally provide at least 100% of the population reference intakes for healthy individuals of the relevant age group, related to the usual energy supply for that group. Enteral feeds are generally delivered via tube but may also be taken orally.

The nutrient composition of enteral feeds should be age adapted (29,30). Despite the lack of evidence, the CoN considers that when paediatric formulas are not available, an adult formulation can be used only after the age of 8 to 10 years.

An energy density of ≈ 1 kcal/mL feed is appropriate for most children, and generally when meeting full nutrient requirements, it also supplies sufficient fluid intake. Feeds with a high energy density (≈ 1.5 kcal/mL) are useful in children with increased energy

TABLE 1. Suggested criteria for nutritional support (4,11)

Insufficient oral intake

Inability to meet $\geq 60\%$ to 80% of individual requirements for >10 days

In children older than 1 y, nutrition support should be initiated within 5 days, and in a child younger than 1 y within 3 days of the anticipated lack of oral intake

Total feeding time in a disabled child >4 to 6 h/day

Wasting and stunting

Inadequate growth or weight gain for >1 mo in a child younger than 2 years of age

Weight loss or no weight gain for a period of >3 mo in a child older than 2 years of age

Change in weight for age over 2 growth channels on the growth charts

Triceps skinfolds consistently <5 th percentile for age

Fall in height velocity >0.3 SD/y

Decrease in height velocity >2 cm/y from the preceding year during early/mid-puberty

TABLE 2. Clinical situations for which EN could be required (11,14,18–20)

Inadequate oral intake
Disorders of sucking and swallowing
Prematurity
Neurologic impairment (eg, cerebral palsy, dysphagia)
Congenital abnormalities of the UGI tract
Tracheoesophageal fistula
Tumors
Oral cancer
Head and neck cancer
Trauma and extensive facial burns
Critical illness
Mechanical ventilation
Severe gastroesophageal reflux
Food aversion, anorexia, depression
Disorders of digestion and absorption
Cystic fibrosis
Short bowel syndrome
Inflammatory bowel disease
Malabsorption syndrome due to food allergy
Cow's-milk protein
Multiple food
Enteritis due to chronic infection
<i>Giardia lamblia</i>
Protracted diarrhoea of infancy
Intractable diarrhoea of infancy
Severe primary or acquired immunodeficiency
Chronic liver disease
Graft-versus-host disease
Intestinal fistula
Disorders of gastrointestinal motility
Chronic pseudo-obstruction
Extensive ileocolonic Hirschsprung disease
Increased nutritional requirements and losses
Cystic fibrosis
Chronic solid-organ diseases: renal, heart, liver
Inflammatory bowel disease (Crohn disease, ulcerative colitis)
Multiple trauma, extensive burns
Growth failure or chronic malnutrition (in addition to above)
Anorexia nervosa
Nonorganic growth faltering
Crohn disease: primary disease treatment for induction of remission
Metabolic diseases

EN = enteral nutrition; UGI = upper gastrointestinal.

requirements, however, if used because the sole feed may not always provide sufficient fluids.

Supplement feeds ("sip feeds") may be provided in addition to normal food to increase energy and nutrient supply when required. Supplements contain a concentrated source of energy, protein, and other selected nutrients, but do not need to provide all of the nutrients in a balanced composition.

Polymeric feeds are usually based on cow's-milk protein, serving as standard formulations for oral and tube feeding and adequate for most patients.

Low-molecular formulas are feeds with oligopeptides derived from protein hydrolysates, and elemental feeds are based on free amino acids. They are indicated in patients with food intolerance to polymeric feeds and may also be indicated in some patients with other disorders, such as severe impairment of intestinal absorption. Because of poor palatability, low-molecular feeds are usually delivered by tube. Low-molecular feeds are more costly than polymeric feeds and should be used only when there is a specific indication.

Enteral formulations are generally *gluten* free, and most are either *lactose* free or contain only low amounts of lactose. *Iso-osmolality* (300–350 mOsm/kg) is considered preferable because feeds with high osmolality (eg, low-molecular diets) may induce diarrhoea in some patients with intestinal pathology. Avoiding high osmolality feeds is particularly important for tolerance of transpyloric feeding (continuous intrajejunal feeding).

Feeds with *dietary fibre* are appropriate for most patients. Fibre and its fermentation products (short-chain fatty acids) have potential beneficial effects on intestinal physiology and the prevention of both diarrhoea and constipation (31,32). Enteral feeds providing dietary fibre were shown to reduce diarrhoea, with hydrolysed guar gum and pectin being superior to soy polysaccharides (33). The use of a mixture of bulking and fermentable fibre has been suggested as a preferable approach (33).

High-fat feeds providing more than 40% of the energy content as lipids and hence with reduced glycaemic loads may provide benefits in patients with stress metabolism (insulin resistance, hyperglycaemia [eg, postsurgical], septicemia, burns) and can reduce CO₂ production. The latter may be of value in hypercapnic patients with pulmonary disease (eg, cystic fibrosis), but the clinical benefit remains questionable. The substitution of part of the fat content by medium-chain triglycerides (*MCT oils*) can be an advantage in patients with severe forms of fat maldigestion and/or malabsorption (severe cholestasis, exocrine pancreatic insufficiency, interruption of enterohepatic bile circulation), severe short bowel syndrome or other causes of low absorptive surface area, and disorders of the lymphatic system. Indiscriminate use of MCT containing formulations should be avoided because MCT contain about 15% less energy per gram than natural oils and reduce essential fatty acid intake. Diets with *high monounsaturated fatty acid* content (>20% of energy) have been proposed to improve insulin resistance, but clinical evidence of benefit in paediatric patients is lacking. The supply of some long-chain omega-3 polyunsaturated fatty acids may be useful to support accretion in membrane-rich tissues and provide anti-inflammatory and immunomodulating effects, but further data on its effects on clinical endpoints are required.

The polysaccharide *carrageenan* derived from red alga (*Iridaea* sp) has been used as an emulsifier and thickening agent. Because carrageenan has potentially allergenic and inflammatory effects, it is not permitted for use in infant formulae in the European Union (34). We consider it prudent to use feeds without added carrageenan in paediatric patients with intestinal damage or intestinal inflammation (35).

For certain conditions, *disease-specific formulations* may be beneficial; these can be tailor-made in hospital kitchens or at home from a variety of components and commercially available modules, or may be available ready-made. Examples are patients with renal disease or hyperammonaemia (feeds with reduced protein contents), severe cholestasis (feeds with part of the lipid content provided by MCT and increased contents of lipid-soluble vitamins), short bowel syndrome (feeds with MCT), galactosemia or glucose/

galactose malabsorption (carbohydrate-modified formulas), and cow's-milk protein/multiple food allergy (formulas based on extensively hydrolysed protein or amino acids). In adults, certain immune-modulating formulae containing long-chain omega-3 fatty acids, nucleotides, glutamine, or arginine appear beneficial in selected patient groups (36,37). Presently, it is unknown whether immune-modulating formulae provide benefit in children. Use of pureed (blenderised) normal foods for tube feeding is not encouraged because of the risk of nutritional inadequacy and microbial contamination.

Statements Standard polymeric feeds based on cow's-milk protein with fibre, which have energy and nutrient content adapted to requirements for age, are appropriate for enteral feeding of most infants, children, and adolescents; these polymeric feeds can serve as the sole source of nutrition. Low-molecular feeds (*oligopeptide feeds* based on protein hydrolysates and *elemental feeds* based on amino acids) are used in selected patients, for example, those with food intolerance or impaired intestinal absorption and/or digestion. Disease-specific enteral formulations may be beneficial in certain circumstances; however, claims of benefit should be evaluated critically.

Recommendation Supplement feeds should be given only as an addition to other foods when enhancement of oral energy and substrate intake is necessary.

Research Needs Only limited data are available on the effects of using different formulations in paediatric patients. The addition of new components and other major modifications of enteral formulations should be evaluated with respect to their suitability and benefit in controlled clinical studies.

ADMINISTRATION OF ENTERAL NUTRITION BY TUBE OR STOMA

Sites (Gastric vs Postpyloric Feeding)

EN delivery may be gastric or postpyloric. The choice of access should take into consideration morphological and functional integrity of the gastrointestinal tract, the duration of EN, and the risk of aspiration. Whenever possible, gastric feeding is preferable to postpyloric feeding because secure positioning of the gastric tubes is easier to achieve and it is more physiological. Bolus feeds and hyperosmolar solutions should not be delivered postpylorically because they may induce diarrhoea.

Postpyloric access is indicated only in clinical conditions in which aspiration, gastroparesis, gastric outlet obstruction, or previous gastric surgery precludes gastric feeding or when early postoperative feeding after major abdominal surgery is planned (11,37). In adults, exceeding absorption capacity (1.5–2.0 kcal/mL) may induce stasis and cause dumping syndrome. Postpyloric feeding needs to be continuous and should be increased cautiously, particularly when high energy and/or hyperosmolar feeds are used. The 2 sites (gastric vs postpyloric) have been compared in both children and adults, but the results are conflicting. A recent meta-analysis of 9 randomised controlled trials (RCTs) (522 adult patients) did not demonstrate any clinical benefit from small bowel compared with gastric feeding in a mixed group of critically ill patients (38). In mechanically ventilated children, 1 RCT (n=74) comparing gastric versus small-bowel feeding showed that those fed transpylorically achieved a significantly greater percentage of energy goal; however, both groups received substantially lesser energy than the ideal. Transpyloric feeding did not protect against aspiration, vomiting, diarrhoea, or abdominal distention (39). Whether the difference in caloric goal achieved is of clinical significance is questionable (40–42). In preterm infants, 1

Cochrane review (43) did not show statistically significant differences between gastric tube and transpyloric feeds in mean body weight or occipitofrontal head circumference at 3 months or at 6 months corrected age. Transpyloric feeding was associated with a greater incidence of gastrointestinal disturbance (relative risk 1.45, 95% CI 1.05, 2.09), and increased mortality (relative risk 2.46, 95% CI 1.36, 4.46).

Recommendations Intra-gastric access should be used whenever possible. Postpyloric access is indicated in clinical conditions in which tracheal aspiration, gastroparesis, gastric outlet obstruction, or previous gastric surgery precludes gastric feeding or when early postoperative feeding after major abdominal surgery is planned. The evidence to support these recommendations is not based on controlled studies. In preterm infants, postpyloric feeding should be avoided.

Routes (Tubes vs Gastrostomy or Enterostomy)

ENS can be provided by replaceable tubes (nasogastric [NG], nasoduodenal, nasojejunal) or via gastrostomy or enterostomy. The likely duration of ENS and the integrity of the upper gastrointestinal tract are the major criteria influencing the choice of the route.

Nasogastric Tube

NG tubes should be introduced only by trained staff or caregivers because of the risk of misplacement and oesophageal or pulmonary perforation (44,45). Methods for tube insertion are detailed elsewhere (46,47). Confirming the position of the NG tube is essential not only on insertion but also on subsequent use. Several methods aimed to verify tube placement exist (46). Radiology is the recommended method but has the drawback of radiation exposure (47,48). Auscultation for “bubbling,” when air is flushed down the tube, is unreliable because bowel and bronchial or pleural sounds are indistinguishable (49). In adult patients, inspection of the type and quality of the aspirate obtained, including pH testing, is advocated (50–52); however, in children, pH testing may be misleading because of gastroesophageal reflux or the buffering effect of milk. To ensure the safety of children requiring an NG tube, it is essential that a bedside method for determining tube placement is developed and applied in the daily routine.

Recommendation Confirming the position of the NG tube is essential during both insertion and subsequent use. A practical, reliable, and evidence-based bedside method in children has yet to be identified.

Nasoduodenal or Nasojejunal Tubes

Placement of nasoduodenal and nasojejunal tubes can be difficult. Methods include a “blind” bedside insertion (53), use of weighted tubes (54), self-propelled tubes (55), fluoroscopic placement (56), endoscopic placement (57), and the use of prokinetic agents such as metoclopramide or erythromycin (58–60). Other approaches include gastric insufflation (61,62), magnetic-assisted placement (63), and a combination of other techniques coupled with electromyographic guidance (64,65). Even with the use of sophisticated techniques, the success rates have not surpassed 75% to 80% (65,66).

Complications of Nasoenteral Tubes

Complications associated with nasoenteral tubes have become less common since the introduction of fine-bore tubes in

TABLE 3. Complications of nasogastric and nasoenteric feeding tubes

	Complications	Cause	Prevention/treatment
Tube-related	Plugging	Incorrect tube care (drug remnants, viscous formula, using gravity not pump, small lumen, yeast colonisation, tube dysfunction)	Flushing (×2 gastric, ×4 nasojejunal for continuous flush) before and after each feeding or medication Open clogged tubes with warm water, papain, carbonated drink, or commercial preparations Replace tube
	Dislodgement	Coughing, sneezing, vomiting, unintentional removal	Check tube position before each feeding Correct repositioning
	Nasopharyngeal discomfort (sore throat, thirst, dysphagia)	Larger, less soft or flexible tubes	Use smaller, soft tubes Change tubes as recommended
	Tracheoesophageal fistula	Presence of both large nasoenteric and nasotracheal or tracheostomy tubes and development of pressure necrosis	Use small soft tubes
Tube misplacement	Endobronchial	Lack of gag or swallowing and cough reflex	Check tube position after insertion and before each feeding
	Intrapleural	Mechanical ventilation	
	Intrapericardial	Altered consciousness	
	Intracranial		
Visceral perforations and associated complications	Oesophageal and tracheobronchial tree	Tube misplacement	Gentle insertion Verify position before securing the tube
	Pneumothorax	Reinsertion of guidewire with the feeding tube in situ	
	Empyema		
	Mediastinitis		
	Pericardial sac		
	Pneumatosis intestinalis		

the 1970s (67,68). Passage is facilitated using a guidewire, and the tubes are more flexible and less likely to cause erosions, oesophagitis, or strictures. Although polyvinyl chloride tubes require frequent replacements (each 3–5 days), fine-bore tubes (silicone and polyurethane) can be left in place for up to 8 weeks. Tube blockage, misplacement, and nonintentional removal are potential problems. A list of complications is provided in Table 3.

Recommendation Polyvinyl chloride tubes require frequent replacements (every 3–5 days); fine-bore tubes (silicone and polyurethane) can be left in place for up to 8 weeks.

Percutaneous Endoscopic Gastrostomy or Enterostomy

As a general rule, when ENS is expected to be long term, feeding via a gastrostomy, or in certain situations enterostomy, should be the preferred route. Optimal timing for gastrostomy insertion remains uncertain but should not be less than 4 to 6 weeks, and in many cases can be longer. Open gastrostomy placement via laparotomy has been largely replaced by the percutaneous endoscopic gastrostomy (PEG) technique, initially described by Gauderer et al (69) (Fig. 1). Indications and contraindications for the use of a PEG are listed in Table 4.

Several studies in adults compared the clinical effects of feeding via NG tubes and gastrostomy (70,71). NG tube feeding had

a higher rate of discomfort and complications (irritations, ulceration, bleeding, displacement, clogging). Gastrostomy feeding was superior with regard to nutritional efficacy, acceptability, and reduced rates of both gastroesophageal reflux and aspiration pneumonia, thus improving quality of life.

In children with neurological disabilities, both NG and gastrostomy feeds improved nutritional status, often accompanied by improved perception of well-being (72). In children with end-stage renal disease on peritoneal dialysis (PD), both methods were associated with similar complication rates, although somewhat different types of complications were seen (73).

Recommendation Long-term EN should be provided using gastrostomy.

Percutaneous Endoscopic Gastrostomy Placement: Preoperative Preparation and Postoperative Care

Before PEG placement, the advantages and disadvantages should be assessed by a multidisciplinary nutrition support team (1), with caregivers being fully involved (Table 4, Fig. 1).

The preoperative preparation should also include obtaining informed consent, laboratory tests (haemoglobin, platelet count, and coagulation studies), and preprocedure fasting (6 hours of solid food, 4 hours of breast milk, 2 hours of water) (74).

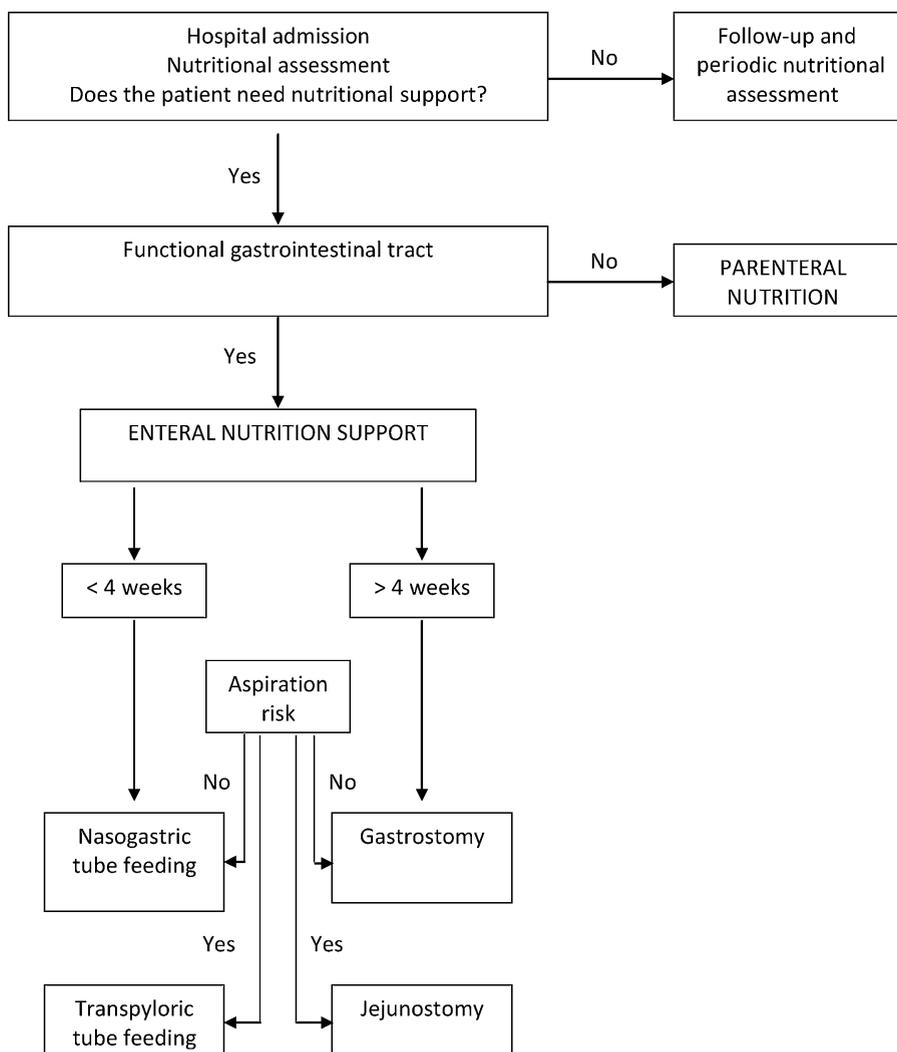


FIGURE 1. Enteral nutrition support decision tree.

Considering antibiotic prophylaxis, in adults, 2 recent systematic reviews of RCTs, 1 with a meta-analysis, concluded that administration of systemic prophylactic antibiotics for PEG placement reduces peristomal infection (75,76). Most guidelines related to adults suggest that a single dose of broad-spectrum antibiotic administered before PEG insertion significantly reduces the incidence of peristomal infection (77–79). In children, a nonrandomised trial showed similar infection rates with a single dose of ceftriaxone prophylaxis compared to 2 doses of ceftriaxone plus oral metronidazole (80). No evidence-based guidelines on the use of prophylactic antibiotics for the insertion of PEG in children are available.

The most frequent source of wound contamination is oropharyngeal flora. Therefore, some preprocedure preparation guidelines in adults recommend oral decontamination with chlorhexidine gluconate 12 hours and immediately before the procedure (81). Application of povidone-iodine in combination with systemic antibiotics was shown to significantly reduce stomal infection at the end of the first week following PEG insertion (82). A sufficiently large abdominal incision and prevention of pressure ischaemia may also reduce the risk of wound infection.

After PEG insertion, the recommended time for resumption of feeding (adults and children) is inconsistent, and varies from 1 to 24 hours. In adults, early (3–6 hours) feeding is as safe as next-day feeding, is well tolerated, and decreases length of hospital stay (83–86). Early refeeding starting after 6 hours and resumption of full feeding within 24 hours is also safe in children (87). PEG aftercare, including wound cleansing, change of first dressing, and adaptation of external fixation (loosening of the external fixation plate to allow free movement of the tube of at least 5 mm), is performed by the specialist nurse after 24 hours. Family training of PEG use and care are taught during the days before discharge (74).

Statements Antibiotic prophylaxis (intravenous cephalosporines) may reduce the prevalence of wound infection. Introduction of feeds after 6 hours and resumption of full feeding within 24 hours has been shown to be safe in children.

Recommendations Despite the weak evidence in children, ESPGHAN CoN recommends antibiotic prophylaxis for PEG placement. Reintroduction of food should be done 6 to 24 hours after PEG placement.

TABLE 4. Indications and contraindications of PEG

Indications	Relative contraindications	Absolute contraindications
Chronic disorders associated with malnutrition (chronic lung disease, congenital cardiac malformations, AIDS, chronic renal failure, congenital malformations, short bowel, Crohn disease)	Failure to transilluminate abdominal wall (obesity, high intrathoracic position of the stomach, marked hepatomegaly or splenomegaly, interposition of colon, previous gastrectomy)	Inability to perform UGI endoscopy (laryngeal or oesophageal stricture)
Neurologic disorders (cerebral palsy, neuromuscular disorders, prolonged coma)	Patient's comorbidity (portal hypertension, severe gastritis or gastric ulcer, massive ascites, peritonitis, peritoneal dialysis, peritoneal metastases, left ventriculoperitoneal shunts)	Uncorrectable coagulopathy
Oncologic disorders (malignant tumors of head, neck, oesophagus before surgery, chemotherapy, or radiotherapy)	Terminal illness with limited life expectancy	
Chronic intestinal pseudo-obstruction for feeding and decompression		

PEG = percutaneous endoscopic gastrostomy; UGI = upper gastrointestinal.

Complications

The success rate of the procedure in adults ranges between 84% and 96% (88). Severe, procedure-related complications, such as perforation, hepatic or colonic injury, serious abdominal haemorrhage, or peritonitis, which require surgical intervention, occur in fewer than 0.5% to 2.5% of adults; PEG-related death has rarely been reported (89). In children, the early complication rate is 8% to 30%, depending on the definition of complications (90–92); complications comprise cellulitis, feeding intolerance, lacerations and perforations, duodenal haematoma, complicated pneumoperitoneum, necrotising fasciitis, and catheter migration.

The most frequent complication is wound infection. Increased infectious complications have been reported after PEG placement in patients with ventriculoperitoneal shunts (VPS; ascending meningitis) or PD catheter (fungal peritonitis). The presence of VPS is not a contraindication and the presence of PEG does not increase the risk of shunt infection; however, it has been suggested that PEG insertion should be deferred at least 1 week after VPS insertion (93). PEG placement before initiation of PD appears to be safe, although following PD, there is a high risk for fungal peritonitis and potential PD failure (94). Antibiotic, antifungal prophylaxis and withholding PD for 2 to 3 days are suggested precautions for lowering this risk. When gastrostomy placement does not occur before or at the time of initiating PD, the risks and benefits of percutaneous versus open placement must be carefully weighed (94,95).

Late complication rates as high as 44% have been described in children, and in some studies, stoma-related complications have been reported in 73% of patients, suggesting that PEG may be associated with significant late morbidity, mainly occurring within the first 2 years after PEG insertion (96). Gastrocutaneous fistula after PEG removal has been reported to occur at a rate as high as 24% of children and sometimes requires surgical closure (97). A retrospective review of 121 children undergoing PEG found a high rate of parental and caregiver satisfaction with the procedure (98). Long-term complications are set out in Table 5.

Modes of Delivery

Although continuous formula infusion is often recommended as a means of improving feeding tolerance and minimising complications, published data are limited. Intermittent bolus feeding is thought to be more physiological, providing cyclical surges of the gastrointestinal hormones that have a trophic effect on intestinal mucosa (99), whereas continuous enteral feeding has been associated with impaired gallbladder emptying in infants (100). Several studies comparing continuous versus intermittent feeding regimens in children and in adults, also including patients in the intensive care unit, showed no significant difference in food tolerance or complication rate (presence of diarrhoea) (101,102). A comparison of continuous with intermittent feeding in children with severe diarrhoea reported improved enteral balance and weight gain in children fed on a continuous schedule (103). Continuous enteral feeding was also shown to improve weight gain in children with complex congenital heart lesions who failed to gain weight adequately despite the use of hypercaloric formulas and nutritional supplementation (104,105). A prospective controlled study in 45 children from an Australian paediatric intensive care unit found that continuous and intermittent gastric feeding regimens have similar outcomes with respect to feeding tolerance and complications (diarrhoea and vomiting) (106,107).

Statements Intermittent feeding is more physiological and therefore preferable as a standard procedure. Continuous feeding has the advantage of providing more energy and better weight gain in selected groups of patients.

Research Needs Research needs include development of a robust bedside method for determining NG tube positioning for routine use, establishing the best way to insert transpyloric tubes, determining the efficacy of transpyloric feeds, developing standardised guidelines for antibiotic prophylaxis before PEG insertion, timing of introduction of feeds after PEG insertion, and prospectively evaluating the complication rate.

TABLE 5. Long-term complications of gastrostomy and enterostomy tubes

	Complications	Possible cause	Prevention/treatment	
Tube-related	Plugging	See Table 3	See Table 3	
	Broken tube or leakage		Replace tube	
	Buried bumper		Avoid excessive tension	
	Dislodgement		Replace immediately	
Local irritation	Migration	Tight fixation, infection	Correct positioning	
	Pain around site		Check fixation and treat infection	
	Skin irritation		Tight fixation, leakage	Check fixation, use PPI
	Granulation tissue		Tube friction	Silver nitrate cauterisation
Local infection	Site bleeding		Local care, PPI	
	Purulent discharge		Apply topical hexacaprone	
Stoma-related	Cellulitis, peristomal abscess		Cleaning and topical antibiotics	
	Enlarged stoma site	Large wall incision	Give systemic antibiotics	
After removal	Leakage of nutrients or gastric juice	Large stoma	Use smaller tube sizes	
	Enterocutaneous fistula		Use smaller tube size, stop feeding and PN	
	Retention of internal bumper		Give conservative and surgical treatment if needed	
			Remove by endoscopy	

PN = parenteral nutrition; PPI = proton pump inhibitor.

COMPLICATIONS OF ENTERAL TUBE FEEDING

Enteral tube feeding may be poorly tolerated for a number of reasons (Table 6) and carries significant risks, the more important of which are considered in detail below. Long-term tube feeding is associated with failure to develop (or regression of) oromotor feeding skills. Early assessment by a nutrition skills-oriented speech-language pathologist and implementation of an oromotor stimulation programme are recommended to reduce the risk of oral hypersensitivity and subsequent feeding difficulties.

Refeeding Syndrome

Refeeding syndrome is a term used to describe the various metabolic complications that can arise as a result of implementing nutritional support (enteral or parenteral) in malnourished patients (108). Problems arise because starvation causes adaptive reductions in cellular activity and organ function accompanied by micronutrient, mineral, and electrolyte deficiencies. The major sources of energy in catabolic patients are fat and muscle; total body stores of nitrogen, phosphate, magnesium, and potassium are depleted. Sudden reversal of catabolism through nutritional support (particularly excessive carbohydrate) leads to a surge of insulin secretion, which causes massive intracellular shift of phosphate, magnesium, and potassium with a subsequent fall in serum concentrations. The clinical consequences of hypophosphataemia include haemolytic anaemia, muscle weakness, and impaired cardiac function, leading potentially to cardiac failure, fluid overload, arrhythmia, and death.

Children with severe chronic weight loss are at highest risk (eg, anorexia nervosa, cancer cachexia), with the greatest risk being during the first week of feeding. Refeeding syndrome, however, is a potential complication of nutritional support in any malnourished patient. Because the nature of refeeding precludes randomised trials of treatment, recommendations are derived from expert opinion. Following a review of the literature, Afzal et al (109) suggested the following strategy for reducing the risk of refeeding syndrome: Before starting nutritional support, assess nutritional status and hydration, serum electrolytes, magnesium, and phosphate; monitor

electrolytes, phosphate, magnesium, calcium urea, and creatinine daily, and assess cardiac status (pulse, heart failure, electrocardiogram, ultrasonography). The initial enteral feeding regimen should be limited in terms of volume and energy content to provide around 75% of requirements in severe cases (<7 years, 60 kcal · kg⁻¹ · day⁻¹; 7–10 years, 50 kcal · kg⁻¹ · day⁻¹; 11–14 years, 45 kcal · kg⁻¹ · day⁻¹; 15–18 years, 40 kcal · kg⁻¹ · day⁻¹). If tolerated, initial intakes may be increased for 3 to 5 days; frequent small feeds with an energy density of 1 kcal/mL should be used to minimise fluid load. Protein intake may start at 0.6 to 1 g · kg⁻¹ · day⁻¹ and increase to 1.2 to 1.5 g · kg⁻¹ · day⁻¹. Supplements are given as follows: Na⁺ 1 mmol · kg⁻¹ · day⁻¹; K⁺ 4 mmol · kg⁻¹ · day⁻¹; Mg²⁺ 0.6 mmol · kg⁻¹ · day⁻¹; phosphate up to 1 mmol · kg⁻¹ · day⁻¹ intravenously and up to 100 mmol · kg⁻¹ · day⁻¹ orally for children older than 5 years of age; hypocalcaemia should be corrected. Thiamine, riboflavin, folic acid, ascorbic acid, pyridoxine, and fat-soluble vitamins must be supplemented and additional trace elements may also be needed. In addition, the National Institute for Health and Clinical Excellence guidelines for adult nutrition are relevant to adolescents (110). For patients who have little food intake for more than 5 days, it is recommended that nutritional support be introduced at 50% of requirements for the first 2 days before increasing to meet full needs if close clinical and biochemical monitoring reveals no refeeding problems. Much greater care is advocated for those patients with the following characteristics: BMI <16 kg/m², unintentional weight loss of >15% within the previous 3 to 6 months, little or no nutrient intake for >10 days, and low levels of potassium, phosphate, or magnesium before any feeding. Besides initially restricting protein and energy intake, these patients should be given thiamine and other B-group vitamins, along with a balanced multivitamin and trace element supplement; supplementation of potassium, magnesium, and phosphate are also likely to be required (110).

Recommendations The potential for refeeding syndrome should be considered whenever nutritional support is instituted; the more malnourished, the higher the risk. Monitoring and supplementations are essential (as outlined above), and energy intake should be advanced cautiously.

TABLE 6. Complications associated with enteral tube feeding

Complication	Cause	Prevention/treatment
Diarrhoea	Unsuitable feed in a child with impaired gut function	Change to hydrolyzed formula or modular feed
	Excessive infusion rate	Slow rate and increase as tolerated
	Intolerance of bolus feeds	Give frequent, smaller feeds, or change to continuous feeds
	High feed osmolarity	Build up strength of feed slowly and give by continuous infusion
Nausea or vomiting	Microbial contamination of feed	Use sterile, commercially produced feeds when possible; prepare other feeds in clean environment
	Drugs (eg, antibiotics, laxatives)	Review drug prescription
	Excessive infusion rate	Slowly build up feed infusion
	Slow gastric emptying	Encourage lying on right side
	Constipation	Give prokinetics
Regurgitation or aspiration	Medicines given at the same time as feed	Maintain regular bowel habit with adequate fluid intake, fibre-containing feed, and/or laxatives
	Psychological factors	Allow time between giving medicines and giving feed, or stop continuous feed for a short time
	Gastroesophageal reflux	Review feeding behaviour; consider referral to psychologist
	Dislodged tube	Correct positioning, feed thickener, drugs, continuous feeds, jejunal tube, fundoplication
	Excessive infusion rate	Secure tube adequately and regularly review position
	Intolerance of bolus feeds	Slow infusion rate
		Smaller, more frequent feeds or continuous infusion

Bacterial Contamination of Feeds

Microbiological contamination of enteral tube feeds given to children at home and in hospital is common (111). It is uncertain how often this results in symptomatic illness, although sepsis has been reported in both adult and paediatric patients, confirming that a certain risk is involved. Children who are immunocompromised, such as those undergoing chemotherapy or when the gastric acid barrier is impaired, may be more vulnerable. Coagulase-negative staphylococci, streptococci, and Gram-negative bacilli are among the organisms isolated from feeds. Risk factors for contamination include the environment and manner in which the feed is prepared, inadequate hand-washing techniques, poor attention to hygiene when handling the feed container and giving set, and repeated topping up of the feed container (with repeated touching of the giving set and transfer of bacteria from the hands). In 1 study, following an enteral feeding protocol that encouraged strict adherence to good hygiene, there was a significant reduction in the proportion of feeds with bacterial contamination, both in hospital and at home (112). The optimum feed hang time is uncertain, but bacterial contamination of commercial products may occur when opening and decanting feeds from source containers, so that frequent feeds may be unwise unless giving sets are also changed (113). Commercially available “ready to hang” closed enteral feeding systems are designed to limit handling procedures to the introduction of the giving set spike into the pack. Although this may reduce the risk of microbiological contamination resulting from poor handling procedures before feeding, retrograde contamination of the set may occur, the risk of contamination increasing with duration of feed (114). Ongoing training of ward staff and careful instruction of home caregivers by specialist nurses is an additional important component in reducing bacterial contamination. This is an area that mandates regular audit.

Recommendation Preparing feeds and setting up feeding systems should be done in a clean environment with

scrupulous attention to hygiene. On the basis of limited evidence we suggest that hanging time does not exceed 4 to 6 hours.

Drug–Nutrient Interactions

Many patients receiving enteral tube feeding will also be taking medications. Unrecognised interactions between drugs and nutrients may adversely affect clinical outcomes. Medications designed to be taken orally are often given via an enteral feeding tube; crushing or dissolving solid preparations to administer in this way can affect drug bioavailability as well as lead to tube occlusion. An enteral feed or 1 of its components may adversely affect the absorption, metabolism, or excretion of a drug (eg, phenytoin). Flushing the tube with water before and after a medication improves drug bioavailability. Many commonly used liquid drug preparations have a high osmolality (>3000) and can thereby provoke diarrhoea when given via a jejunal tube if not first diluted (115).

Recommendations Before administering medicine via an enteral feeding tube, all of the alternative routes should be considered; giving enteric coated and slow-release tablets via the tube should be avoided. If the tube is the only route available, then a liquid preparation is preferable; tablets must be thoroughly crushed and mixed with water; and the contents of gelatine capsules can be dissolved in warm water. The tube should be flushed with water before and after administration of each medication.

Micronutrient Deficiency or Excess

Although the choice of specialised paediatric formula has rapidly expanded, the optimal micronutrient content has not been fully defined. The European Union Commission Directive on Dietary Foods for Special Medical Purposes stipulates the composition of feed (8) with recommendations including minimum and

maximum values for vitamins, minerals, and trace elements; deviations are permitted for disease-specific formulations. Surprisingly, with the exception of calcium and vitamin D, no distinction is made between adult and paediatric feeds. In fact, there is little information on the bioavailability of vitamins, minerals, and trace elements in paediatric feeds and there is variation in absorption and utilisation of micronutrients. In addition, there is deterioration in the vitamin content of feeds throughout their shelf life. For example, gross clinical scurvy has been described with a commercial feed despite an apparently adequate intake of vitamin C (116). Such cases highlight the fact that feed preparation and administration as well as drug–nutrient interactions may affect nutrient delivery. Conversely, high blood concentrations of vitamin B₁₂ and copper have been described in some children receiving ENS, suggesting that upper limits for nutrient intake also merit further examination (117).

Recommendation Trace element and vitamin status should be monitored.

Research Needs Research needs include identifying risk factors for refeeding syndrome, developing protocols that minimise the risk of bacterial transmission from enteral feeding systems, and defining the optimal micronutrient content of liquid feeds.

HOME ENTERAL TUBE FEEDING

The aims of home enteral tube feeding (HETF) include provision of effective nutritional support, promotion of patient and family autonomy (taking into account their preference for route of feeding and care plan), ensuring safe and trouble-free maintenance of nutritional support, and maximising the potential for improved lifestyle and optimised disease management. All of the children in the community receiving enteral tube feeding should be supported by a multidisciplinary team, where possible including dietitian, specialist nurse, general practitioner, paediatrician, and community pharmacist. Close liaison between the team and parents or caregivers regarding the purpose of nutritional support, prescription of feed and equipment, and potential problems is essential. Suggested standards of practice for HETF have been published by the British Association for Parenteral and Enteral Nutrition (118). Good communication between patient, family, and health care professionals is a prerequisite for effective discharge planning. The needs of the child and family must be clearly identified to prepare transfer from hospital to home. It is also essential that continuing care arrangements are in place with coordinated action from all of the agencies involved (eg, family, health care professionals, social services, education, voluntary bodies). Equipment supply should be arranged before discharge.

Parents or caregivers and children (when of appropriate age) should receive training and information from members of the multidisciplinary team on the following topics: information about the reasons for HETF and likely duration; safety aspects of care; checking tube placement; infection control issues; hand-washing techniques; feed preparation (use ready-made feeds whenever possible); familiarity with feeding equipment; advice regarding social and practical implications for child and family; problem-solving advice and what to do in an emergency; the importance of maintaining oral stimulation; telephone contacts for hospital and community staff; and detailed information about how to obtain equipment and supplies.

The use of an enteral feeding pump is essential for continuous feeding and is preferable in bolus feeding. EN pumps should be easy to set up, operate, and clean, and be durable, small,

lightweight, portable, and accurate. There should be an optional bolus feeding setting available, and the pump must be tamper proof, operate quietly, have occlusion, have empty and low battery alarms, and be reliable. Teaching material should be provided, including a step-by-step guide to setting up the pump, written instructions on the side of the pump and in pamphlet form, and a training video. Cost and servicing arrangements are important considerations when considering pump purchase.

MONITORING ENTERAL NUTRITION SUPPORT

The main objective of monitoring nutrition support is to ensure safety and optimal growth and to detect and treat clinical complications as quickly as possible. It is important to consider and regularly review the objectives of nutritional support in individual patients and assess the extent to which these have been achieved. There may be a need to alter the type of nutritional support to improve effectiveness or minimise metabolic risk. Monitoring will include regular review of nutritional status including intake, weight, height, biochemical and haematological indices, general clinical state, well-being, gastrointestinal function, tube integrity, and any tube-related complications. The type and frequency of monitoring will depend on the nature and severity of the underlying disease.

Recommendations The objective of nutritional support should be regularly evaluated. Involvement of a nutritional support team is recommended.

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