Enteral feeding in children

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Introduction

The progress achieved in recent years in many aspects of medical care, including the advent of trained paramedical personnel, on-site emergency assistance, and advances in pharmacology and electronics, has resulted in increased survival for many children. These children, who previously would not have survived, frequently remain unable to ingest nutrients by mouth for prolonged periods. As a result of illness and/or continued hospitalization, many children become unable or unwilling to ingest orally adequate calories to achieve growth or to prevent, or recover from, malnutrition. Although in major medical centers the necessary calories may be provided by intravenous feeding, the technique is not free from complications, it is expensive, and not always available. In this article, we will review the principles of enteral nutrition and its application to the paediatric population.

Historical aspects

Development of tube feeding

Tube feeding evolved in the 16th century from tubes used to extract foreign bodies from the oesophagus or to dilate oesophageal strictures [1]. In 1790, Hunter designed and successfully employed a tube to feed a patient who had suffered paralysis of the muscles of deglutition [2]. In the first half of the 19th century, several developments were reported in the design of a syringe and pump connected to a tube. This mechanism was used to feed patients who were unable or unwilling to eat, a method that became quite popular in asylums for the insane, particularly in England [3]. Duodenal feeding was described by Einhorn, who used a tube which he had developed for aspirating duodenal contents. The tube had a small metal capsule at the end [4]. In 1939, Stengel and Ravdin described a nasogastric method for feeding patients post-operatively [5].

Development of elemental diets

As the use of tube feeding became widespread, feeding solutions became more complex. Protein hydrolysates were used as sources of amino acids and dextrose, sucrose, and partially hydrolyzed starch as maltodextrin were employed as carbohydrate sources [5]. As the importance of vitamins and minerals gained recognition, and as they became available, they were added to the formulations. These diets were distinguished from previously-used feeds, which were composed of milk as casein and puréed vegetables and fruits, by the absence of whole protein, a minimal fat content, and by formulations that would coagulate [3]. Over the ensuing years, numerous preparations were developed and various investigators demonstrated that animals could be maintained on chemically defined, nutritionally complete, enteral diets. Winitz et al. reported extended metabolic studies of male volunteers who remained in nitrogen and weight balance for up to 19 weeks, while fed exclusively a chemically defined diet similar to that used in rats [6, 7]. Stool bulk was remarkably low, while
serum cholesterol fell by approximately 30%. Improved survival after different noxious stimuli, e.g. haemorrhagic shock, intestinal ischaemia, and post-radiation enteritis, has been demonstrated in animals fed an elemental diet as opposed to a regular diet [3]. Defined-formula diets were used in studies of impaired gut function or congenital errors in amino acid metabolism. Thus a role for defined-formula diets began to emerge in the management of abnormalities of digestion and absorption in man [3].

Physiological aspects

Gastric emptying

The emptying of liquids from the stomach is thought to be primarily a function of the pressure gradient between the stomach and the duodenum. The rate of liquid-emptying from the stomach increases linearly with increasing intragastric pressure [8]. Increasing the osmolarity of a solution results in slower gastric emptying [8]. Hunt and Stubbs demonstrated that the rate of gastric emptying of a meal could be predicted by its nutritive density, i.e., the kilocalories/unit volume present [8]. Isocaloric amounts of fat, carbohydrate, and protein leave the stomach at similar rates.

These concepts of gastric emptying must be considered in a number of circumstances, e.g. when bolus feeds are administered by way of a nasogastric tube or to determine whether continuous infusion rather than bolus feeding may be preferred. Such considerations arise, for example, when large volumes or solution with high carbohydrate concentrations and/or high osmolarity are used.

Protein

The belief that free amino acids were the best form for the absorption of nitrogen led to the design of elemental diets in which free amino acids were the nitrogen source. Recent information, however, indicates that unhydrolyzed peptides can be absorbed by the jejunal mucosa using mechanisms which are independent of specific amino acid entry [9]. Thus, di- and tripeptides, rather than free amino acids, have become the nitrogen source in many liquid preparations [10].

Carbohydrate

Because many patients may suffer from primary or secondary lactose malabsorption, lactose is usually eliminated from formulae to be administered enterally. Most modern formulae contain a mixture of sucrose and glucose oligomers, or glucose oligomers alone. The advantage achieved through the use of these carbohydrates, compared with glucose, is a lower osmolar load.

The addition of fibre may be necessary to prevent constipation in patients whose only source of nutrition is the liquid formula.

Fat

Most formulations contain vegetable fat in the form of long-chain triglycerides or a combination of long- and medium-chain triglycerides. Medium-chain triglycerides (chain length C8 to C10) are water soluble, and therefore a significant proportion can be absorbed without prior lipolysis and micelles formation. In addition, they do not undergo esterification and therefore do not form chylomicrons. They are delivered to the system through the portal vein.

Enteral feeding concepts

The enteral feeding route should be used whenever possible and should be considered when a patient is unable or unwilling to ingest sufficient calories by mouth. When the decision is made to use tube-feeding in a particular patient, it is necessary to determine whether nasogastric, nasoduodenal, nasojejunal, gastrostomy, or jejunostomy is to be
Enteral feeding in children

employed, and whether the formula will be administered as a bolus or a constant infusion. If it is known that the patient will require enteral feeding for a period of 3 or more months, serious consideration should be given to creating a gastrostomy or a jejunostomy. Jejunostomy feeding, however, is not commonly used in children; it is reserved for cases of proximal small bowel resection in order to administer the feed distal to the surgical anastomosis, and in patients with severe vomiting. In addition to choosing the appropriate formula, the mode of delivery needs to be tailored to the individual needs of the patient. Positive mineral, fat, and nitrogen balances have been achieved, with success, in patients with impaired intestinal absorption, when continuous rather than intermittent infusions were administered [11]. Stool output was less in stressed patients or in those with malabsorption disorders when feeds were delivered continuously [12, 11]. Moreover, continuous infusion may allow a greater caloric intake in patients who would otherwise tolerate limited amounts of bolus feeds because of vomiting or early satiety [13]. Although feeds can be administered throughout the day in hospitalized patients, administering them to most ambulatory patients becomes more complex. When patients go home, their mobility is increased if their feeds can be administered during the night as a constant infusion, and their regular food or special diet ingested or administered (by tube as a bolus) during the day.

When constant infusion is the method of feeding, particular attention must be given to the timing of enteral medication, because many medications must be administered in the fasting state. Serum drug levels should be monitored closely when continuous feeds are begun.

As a general rule, enteral feeds can be started at a hypotonic concentration, approximately one-quarter to one-half strength, depending on the particular problem of the patient. This becomes even more important if feeds are delivered to the jejunum. The initial volume should be about 25 to 50% of the maintenance fluid requirement and the balance of the fluid needs must be given intravenously. After 12 to 24 hours of good tolerance, the rate of infusion or the concentration of the formula can be increased progressively until the volume and caloric needs have been achieved. Increases in concentration and rate should be made independently. When the formula is administered at the desired concentration to patients fed by constant infusion, the rate may be increased every 2 or 3 hours by small amounts to achieve the desired volume in 24 to 48 hours.

Tolerance to enteral feeds is evaluated on the basis of gastric residual volumes, lack of vomiting and diarrhoea, or abdominal discomfort. To check for gastric volumes, the gastric contents are aspirated and the amount retained in the tube is deducted from the total volume administered. This procedure should be performed every 2 to 3 hours during the first few days. If the quantity is not greater than the amount delivered in the previous 2- to 3-hour period, the gastric residual is normal. If the residual is greater than the amount delivered in the previous 2 to 3 hours, the infusion should be stopped for 1 or 2 hours. The position of the tube should be reassessed to make certain that the pyloric outlet is not obstructed. At the beginning of treatment, gastric retention is more common at night; thus, the rate of nocturnal infusion may need to be advanced more slowly [14]. Frequent, small watery stools are not unusual, particularly at the start of continuous feeds. Stools should be checked at the bedside for pH and the presence of carbohydrates. If the stool pH is 5.5 or greater and negative for carbohydrates, feeds should be continued without alteration. Nursing personnel and caretakers should be warned about the likelihood of frequent and small watery stools, so that this finding will not be misinterpreted as diarrhoea.

Follow-up

Patients who have a nasogastric tube frequently complain of a sore throat after the tube has been in place for several days. In addition, mucus may accumulate in the nostril where the tube is placed, and sometimes mucopurulent and/or bloody discharge may also occur. The nose should be kept clean and the tube immobilized after the appropri-
ate addition of lubricant to prevent unnecessary erosion to the nostril. Whenever the tube is removed, it should be reinserted in the opposite nostril.

**Gastrostomy**

Gastrostomy feeds, which bypass the processes of sucking, chewing, and swallowing, are indicated in children in whom oral intake is impaired and is expected to remain so for a prolonged period, greater than 3 months. Although this approach may seem aggressive to some parents and physicians, it simplifies the task of feeding patients who may swallow with great difficulty and in whom feeding becomes a lengthy and frustrating process. The gastrostomy can be performed surgically or transcutaneously with the aid of endoscopy [15]. Recently, with the advent of new devices (“buttons”) that can be applied to the gastrostomy, its management has become simpler.

**Nasojejunal and jejunostomy feeds**

Nasojejunal feeds have been used mainly in premature infants, and thus far studies have not shown significant advantages over intragastric feeds. Perhaps the only patients, for whom intrajejunal feeds are indicated, are those with severe gastrooesophageal reflux in whom nasogastric feeds have failed, children with psychogenic vomiting while psychotherapy is in progress, and children with recent proximal small bowel resection in whom intravenous nutrition cannot be administered.

**Physiological response to enteral feeding**

*Regulatory peptides and enteral feeding*

The enterally-fed newborn infant responds to milk feeds with a surge of blood peptides, such as growth hormone, gastrin and enteroglucagon [16]. No similar increments in blood peptides have been observed in infants who have never been fed enterally, or who have received only intravenous fluids during the first 6 days after birth [17]. The amount of milk needed to induce these surges seems to be small [18]. Infants who receive milk by continuous infusion into the stomach and those who are bolus-fed have an increase in serum peptide levels, compared with preprandial levels, which suggests that the secretion of peptides is triggered, irrespective of the feeding mode. Aynsley-Green *et al.* have demonstrated, however, that major differences exist in the endocrine milieu of the continuously-infused infant, compared with that of the bolus-fed infant [19]. The differences are related to the development of cyclical responses to the feeding; i.e., the bolus-fed premature infant experiences major cyclical changes in hormones and metabolites that are not observed in the steady-state circumstances of the continuously-fed infant [19].

*The effect of enteral feeding on energy expenditure*

An increase in energy expenditure above resting metabolic rate occurs after a meal [20, 21]. The increase is termed the “thermic effect of food”, and is proportional in magnitude and duration to the size of the ingested meal [20, 22]. The total thermic effect of food may comprise between 2 and 17% of the energy in a feed [23]. Hill *et al.* compared the thermic response after ingestion of a meal with that after the delivery of an equivalent amount of food directly into the stomach [24]. The authors found that the thermic effect of food after the tube-delivered meal was not significantly different in magnitude or duration from that after ingestion of the meal, both meals resulted in similar changes in respiratory quotient. The authors concluded that the major portion of the thermic effect of food arises after food reaches the stomach, and that very little is produced by sensory factors or by the mechanical act of eating.

In a related study, Heymsfield *et al.* studied the bio-energetic and metabolic response to continuous versus intermittent nasogastric feeding [25]. These authors departed from the principle on which most workers in the field of thermogenesis
agree, i.e., that fuel synthesis and breakdown account for a measurable fraction of daily energy losses, and that between 5 and 10% of the total caloric intake may be needed to compensate for this source of energy depletion. Continuous-maintenance fuel infusion may result in limited fuel storage, a lowering of thermal energy losses, and a reduction in the amount of dietary energy needed to maintain homeostasis. In a comparison of one week of continuous formula infusion with one week of intermittent formula infusion, Heymsfield et al. found a reduction in resting thermal energy losses of 113 kcal/day (472 kJ/day) in the group fed by continuous infusion [25]. A small, non-significant weight loss, observed when subjects were fed continuously, was attributed to a negative fluid and mineral balance of uncertain cause. Thermal losses were similar during intermittent feeding, with the exception of the thermic effect of food which produced an additional average of energy loss of 115.7 kcal/day (483.6 kJ/day). Total resting and sleeping 24-hour energy expenditure was significantly lower during continuous formula infusion compared with intermittent feeding.

Enteral versus parenteral feeding

Despite advances in intravenous alimentation technology, enteral feedings have several advantages: they induce physiological gastrointestinal responses, result in fewer complications, and are less expensive. In a comparison of an elemental diet with total parenteral nutrition, Allardyce et al. demonstrated that enterally-fed patients were able to tolerate a greater nutritional intake than a comparable group which received total intravenous nutrition [26]. Patients fed enterally had a more positive nitrogen balance and were able to tolerate greater quantities of protein and calories than those fed intravenously. McArdle et al. compared a parenteral nutrition formulation, in which the majority of calories came from glucose, with an enteral solution in which glucose polymers were substituted for glucose. Although carbohydrate content was the same in both formulations, the osmolarity was reduced in the enteral solution [27]. Parenterally-fed patients has significantly higher serum insulin levels, which resulted from biochemical fatty acid deficiency [28]. The enterally-fed patients had neither hyperinsulinaemia nor biochemical fatty acid deficiency. It is possible that the response to nutrients, administered by way of the gut, may be different from that to nutrients administered intravenously [29]. Inasmuch as fatty liver has rarely been reported in patients who receive enteral nutrition, there may be a lower insulin response when carbohydrate is administered through the gastrointestinal tract [29]. Recent studies in animals suggest that compensatory hyperplasia occurs after small bowel resection in enterally-fed animals, as opposed to those which receive equivalent calories intravenously [30].

Complications of enteral feeding

Occlusion of the feeding tube is perhaps the most common problem associated with enteral feeding. Occlusion may be prevented by irrigating the tube with water or saline whenever the feed is stopped, or at least every 8 to 10 hours if the infusion is delivered continuously. The amount of water should not exceed that needed to flush the tube, to avoid problems of fluid overload in patients with fluid restriction.

Other problems that may arise from enteral feeding are nasal or oropharyngeal irritation, dislodgement of the tip of the tube into the oropharynx because of poor tube placement in the nose, or as a result of sever coughing [31], placement of the tube in the trachea, or otitis media.

If the nasogastric tube should progress into the jejunum, a formula that was previously tolerated may produce diarrhoea, vomiting and/or abdominal pain. Diarrhoea also can be caused iatrogenically when excessive amounts of fluids are administered (over 200 ml/kg/day), or from contamination of the formula which has been left at room temperature for long periods. A fresh supply of formula is recommended at least every 4 to 6 hours. Studies have shown that bacterial growth
can occur in enteral nutritional solutions, despite meticulous cleansing of mixing equipment and the use of sterile water for reconstitution by trained personnel. Septic syndromes have been described with the use of needle catheter jejunostomies in adults [32].

Since the antimicrobial protection of gastric acidity is bypassed by the use of jejunal instillation, and several jejunal host defence mechanisms may be impaired in critically ill patients, the enteral feeding regimen is not devoid of potentially severe complications.

Berezin et al. describe the development of significant gastro-oesophageal reflux secondary to gastrostomy tube placement in 5 children with severe psychomotor retardation [33]. These authors suggest that continuous feeding may resolve the problem, but in some patients definitive anti-reflux surgery may be needed.

Use of home tube feeding

Green et al. have described the advantages of using home enteral feeding in patients with a variety of underlying disorders [34]. Potential patients must be evaluated carefully by medical personnel. The parents must be willing to administer the feeds at home, must be capable of learning the procedures, and must assure supervision during the day hours. Before the patient leaves the hospital, it is imperative that caretakers have learned the procedures well. In the USA, companies are available which will deliver all the supplies and formulae to the home and will even provide nursing personnel for supervision. This system has reduced hospitalization costs and, in many instances, has allowed the parents and patients to lead a more normal life [35].

Reinstituting oral feeds in enterally-fed children

For both physiological and psychological reasons, attempts should be made to continue some degree of oral feeding in every child who is capable of swallowing. On the basis of physiological considerations, oral feeds will continue to stimulate normal mechanisms related to salivary, gastric, pancreatic, and biliary secretion, taste buds will continue to be stimulated, and the normal function of chewing and swallowing will be exercised by the patient. From a psychological perspective, enteral feeding is a mechanical process; eye to eye contact, as well as body contact with the patient often is minimized. Therefore, whenever possible, every attempt should be made to continue some oral feeding as a mean of preserving physical and eye contact with the child, even if only nutritionally insignificant amounts can be administered orally.

Reinitiation of oral feeds can be one of the most severe problems encountered in weaning children fed enterally or parenterally for a prolonged period. Many of the patients develop anorexia and/or refuse to eat by mouth. This pattern is particularly common in infants who have been extremely sick, e.g. newborns with persistent additional oxygen requirement who may refuse to eat until they are approximately 3 years of age [35]. Blackman and Nelson described a group of 17 children under 4 years of age who had gastrostomies and were evaluated for the possibility of reinitiating oral feedings [31]. The authors recommended that parents should not attempt to establish oral feeds on their own, and that a programme established by specialized personnel be undertaken. Specialized personnel succeeded in reinitiating oral feeds at the high price of protracted and stressful effort. Although weaning enterally-fed children may be successful, the time required for some children, particularly those with neurological impairment, to ingest sufficient calories is such that caretakers may prefer to continue giving the majority of calories by gastrostomy. When patients have impaired swallowing, it may be preferable to continue giving most of the calories through the gastrostomy.

Use of enteral feeding for specific disorders

Gastro-oesophageal reflux

Infants with severe vomiting due to gastro-oesophageal reflux may have impaired growth as a result of inadequate caloric intake. Although many
Infants respond satisfactorily to medical treatment and start to gain weight, e.g. those in whom malnutrition requires the intake of a greater amount of calories for catch-up growth, or those who have significant oesophagitis that impairs oral intake, or those in whom reflux is severe, may benefit from nasogastric feeds [36]. Formula can be administered as a constant infusion into the stomach so that if reflux occurs, the amount vomited is small, and in many instances vomiting can be avoided altogether. The use of this technique may improve the nutritional state of the patient. If fundoplication is still needed, the patient will be at a considerably lower surgical risk as a result of an improved nutritional state [36]. We have used this system with success in patients with oesophagitis due to gastro-oesophageal reflux or Candida, and in patients with reflux oesophagitis secondary to ascites, cystic fibrosis, or other disorders. Many patients have gone home and continued nasogastric feeding for one or more weeks until oral feeding could be resumed without significant vomiting. Nasogastric tubes, however, also may cause oesophagitis.

**Diarrhoea**

Anorexia frequently accompanies both acute and chronic diarrhoea. The impact of anorexia and ongoing stool losses during gastro-enteritis may have devastating effects on the nutritional state of a patient. Nasogastric feeding may be used in such circumstances to overcome the transient period of anorexia and provide early nutritional rehabilitation.

Many children with chronic diarrhoea have difficulty tolerating carbohydrate at the concentrations required to achieve weight gain. We have found that for such cases a formula, that was not well tolerated previously as a bolus feed, may cause no problem when administered as a constant infusion.

Parker et al. compared continuous intragastric feeds to intermittent oral feeds in 9 infants with protracted diarrhoea and malnutrition, and 2 infants with surgical short bowel. The authors found that continuous nasogastric feeding caused significant increases in enteral balance of the major nutrients, whereas intermittent feeds resulted in negative or only slightly positive enteral balance [11]. Orenstein studied 13 infants with intractable diarrhoea and observed that both continuous enteral nutrition and total parenteral nutrition corrected malnutrition, but continuous enteral nutrition was associated with faster resolution of malabsorption and diarrhoea, fewer complications, and less expensive hospitalization [37].

**Inflammatory bowel disease**

Ten to 40% of children with inflammatory bowel disease will respond to nutritional supplementation with increases in linear growth and correction of delayed sexual maturation. There is strong evidence to support the hypothesis that malnutrition is one of the main causes of growth retardation in children with inflammatory bowel disease. Inadequate intake may be secondary to anorexia which can be caused by chronic illness, or to diarrhoea and/or abdominal pain triggered by food intake. Morin et al. describe 4 children with protracted growth retardation, due to Crohn's disease, who received a continuous elemental diet with no other form of treatment during a 6-week period [38]. All patients experienced complete remission of symptoms, improved nutritional status, and significant height and weight gain. Sanderson et al. had a similar experience with 17 children [39].

**Enteral feeding in other diseases**

Vanderhoof et al. described 11 infants with complex congenital heart lesions who were given continuous enteral infusions after failure to gain adequate weight, despite the use of hypercaloric formulae and nutritional supplementation [13]. Strife et al. reported improved growth in 3 uraemic children fed nasogastrically [40].
Enteral feeds can be used successfully in debilitated patients with moderately severe pulmonary disease, such as cystic fibrosis. As in many other forms of malnutrition, enteral feeds through a nasogastric tube can be used in the early treatment phase of patients with anorexia nervosa.

**Material used**

Pumps for continuous gastric or enteral infusion are of the rotary, peristaltic type and are equipped with battery support. The rate of infusion is controlled electronically and can be adjusted to deliver volumes of between 1 and 300 ml/h in 1 ml increments. The pressure of the pump is enough to deliver formulae of varying viscosity, even through small bore feeding tubes. Pumps feature a variety of audio and visual alarms in case of occlusion, low battery power, empty bag, etc.

Tubes for enteral feeding are made of soft material such as silicone rubber, polyurethane, or other registered compounds and require either a stylet or a weighted tip to facilitate their passage through the pylorus. Some tubes are radio-opaque. Unweighted tips are used for nasogastric feeding. Tube sizes range between 1.7 and 6.02 mm external diameter, and from 50 to 109 cm in length.

**Summary**

There are multiple indications in infants and children for enteral feeding delivered either continuously or intermittently, intragastrically or intraduodenally, by nasogastric or gastrostomy routes. Despite the safety and overall simplicity of this feeding method, as with any other type of therapeutic intervention, close supervision is necessary. Caretakers and nursing personnel must be instructed as to the potential benefits of the technique, but it is imperative that they understand one possible consequence of prolonged enteral feeding: patients may refuse to eat, a condition which may be difficult to overcome. Thus, if enteral feedings are to be used, sucking and swallowing mechanisms must be stimulated continuously, so as to diminish difficulties in weaning patients to oral feedings.

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**References**


