7 Gastroenterology

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Introduction

Gastroenterology is one of the most interesting and challenging areas in paediatric dietetics. The medical conditions encountered are diverse and require an understanding of normal gastrointestinal (GI) function before correct dietetic advice can be given. Problems as varied as diarrhoea, constipation and GI dysmotility can affect normal intake and absorption of nutrients. Manipulation of feeds and diet is often the primary treatment for the underlying condition and carers need careful explanation of the principles of the feed and diet prescribed.

Nutritional requirements

These vary according to the underlying disorder. For GI disorders that do not result in malabsorption, normal requirements for most nutrients will suffice, with additional energy and protein required for catch-up growth.

When malabsorption is present, requirements for all nutrients are raised to cover stool losses, particularly fluid, energy, protein and electrolytes. Most infants will have high to very high requirements. Careful monitoring of nutritional status, by anthropometric and biochemical means, is needed.

Table 7.1 can be used as a guide for requirements for infants with malabsorption who are fed enterally and are based on actual rather than expected weight.

Table 7.1 Suggested requirements for infants with malabsorption.

Energy	High	130–150 kcal/kg/day (540–630 kJ/kg/day)
	Very high	150–220 kcal/kg/day (630–900 kJ/kg/day)
Protein	High	3–4 g/kg/day
	Very high	Maximum 6 g/kg/day
Sodium	High	3.0 mmol/kg/day
Potassium	Very high	4.5 mmol/kg/day
Fluid	High	180–220 mL/kg/day

Fluid and dietary therapy of acute diarrhoea

Acute diarrhoea remains one of the leading causes of childhood morbidity and mortality in developing nations, with an estimated 5–18 million deaths attributed to this cause each year. In industrial nations the mortality rate is much lower. Infants and children are particularly vulnerable to the effects of acute diarrhoea because of their greater relative fluid requirements and their susceptibility to faecal–oral agents.

The causative mechanisms in the GI tract are:

- Increased secretion
- Decreased absorption

Often these co-exist to produce an increased fluid load that exceeds the colonic absorptive capacity, resulting in diarrhoea. Both viral and bacterial pathogens can affect the gut in this way.

Transport of glucose and amino acids is an active process and requires the presence of a sodium gradient across the brush border membrane maintained by the Na^+–K^+ ATPase pump. The movement of water in the gut is a passive event driven by the movement of solute. The regulation of electrolye transport is controlled by several mediators and inhibition of these pathways results in poor absorption and active chloride secretion into the gut.

In infective diarrhoea, decreased absorption is not necessarily caused by reduced villous size. With increased cell loss, immature epithelial cells replace fully differentiated, mature absorptive cells. These cells have defective electrolyte and nutrient transport and functional impairment may be severe. This situation is worsened by cycles of fasting and starvation commonly seen in infants and children with acute diarrhoea in developing countries.

Oral rehydration solutions

Oral rehydration therapy is used to correct dehydration and maintain hydration. The sodium–glucose coupled transport mechanism stimulates water and electrolyte transport. This process is preserved in acute diarrhoeal disorders.

Specific recommendations for the composition of oral rehydration solutions (ORS) for children were published by the European Society of Paediatric Gastroenterology and Nutrition (ESPGAN) in 1992 [1]:

- Carbohydrate should be present as either glucose or glucose polymer at concentrations between 74 and 111 mmol/L
- ORS should contain 60 mmol/L sodium (compared with 90 mmol/L recommended by the World Health Organization [WHO] in developing countries) to minimise the risk of hypernatraemia
- Potassium should be added to replace stool losses
- Osmolality should be low (200–250 mOsm/kg H_2O) to ensure optimal water absorption

Table 7.2 Oral rehydration solutions (ORS) available in the UK.

	mmol/L			
	Na^+	K^+	Cl^-	CHO
Dioralyte (powder) (Aventis Pharma)	60	20	60	90 (glucose)
Electrolade (Baxter)	50	20	40	111 (glucose)
Rapolyte (Provalis)	60	20	50	110 (glucose)
Dioralyte Relief* (Aventis Pharma)	60	20	50	30 g (rice starch)
WHO Formulation Oral Rehydration Salts	75	20	65	75 (glucose)

* Effervescent and flavoured preparations are not suitable for young infants.

Systematic reviews have confirmed that this is still the best composition of ORS to use in children admitted to hospital with diarrhoea [2]. There is no evidence of benefit in reduction of stool loss by the use of ORS containing rice powder in non-cholera diarrhoea [3]. ORS available in the UK are summarised in Table 7.2.

Feeding during acute diarrhoea

For many years it was common practice to stop feeds during diarrhoeal episodes. It was thought that decreased lactase activity, chiefly associated with rotavirus gastroenteritis, would cause lactose malabsorption if milk feeds were introduced too early and that food proteins could be transported across an impaired mucosal barrier and cause sensitisation [4]. Consequently, bottle fed infants with gastroenteritis were fed ORS alone for 24 hours followed by the introduction of dilute feeds. This advice resulted in a reduced nutritional intake at a time when requirements were increased because of infection [5].

A meta-analysis of randomised clinical trials published in 1994 showed that the routine dilution

of milk feeds and use of lactose free formula was not justified in the treatment of infants and children with acute diarrhoea [6]. A multicentre European study has shown that the complete resumption of a child's normal feeding after 4 hours of rehydration with ORS led to a significantly greater weight gain during hospitalisation and did not result in worsening or prolonged symptoms [7]. This is especially important in developing countries where children may already be malnourished.

In 1997, ESPGAN published recommendations that management of gastroenteritis should consist of oral rehydration with a low osmolar ORS for 4 hours (100 mL/kg over 4–6 hours in moderately dehydrated patients), followed by resumption of normal feeding [8]. Supplementing the usual feeds with ORS (10 mL/kg/liquid stool) can prevent further dehydration. Breast feeding should be continued at all times with supplementation of ORS.

Use of lactose free formula

There is no evidence to support the use of lactose reduced or cow's milk protein free formula in infants and children with acute diarrhoea, even if the infective agent is rotavirus. A very small minority of patients who show signs of feed intolerance (defined as worsening of diarrhoea with acidic stools containing >0.5% reducing substances) may need the temporary use of a lactose free formula (Table 7.3).

A multicentre study performed in 29 European countries showed that only a minority of physicians were following the ESPGAN guidelines. Children were still being fed ORS alone for inappropriately long periods of time and over 50% of physicians were prescribing lactose free formulas routinely following a diarrhoeal illness [9]. Guidelines for the optimal management of gastroenteritis need to be promoted to primary care physicians, health care workers and parents.

Table 7.3 Lactose free, cow's milk protein based formula available on prescription in the UK.

Galactomin Formula 17 (Scientific Hospital Supplies)
Enfamil Lactofree (Mead Johnson)
SMA LF (SMA Nutrition)

Congenital chloride losing diarrhoea

This is a selective defect in intestinal chloride transport in the ileum and colon which is inherited as an autosomal recessive trait. Life-long secretory diarrhoea occurs with high chloride concentrations. It has been reported in most populations including Britain; however, it is most commonly seen in Finland and the Arabian Gulf.

In the past it generally resulted in severe lethal dehydration. Watery diarrhoea is present from birth but often goes unnoticed as the fluid in the nappy is thought to be urine. Dehydration occurs rapidly followed by disturbances in electrolyte concentration causing hyponatraemia and hypochloraemia with mild metabolic acidosis.

Treatment

As the intestinal defect cannot be corrected, treatment requires replacement of the diarrhoeal losses of chloride, sodium and water. Initially, this may need to be given intravenously but this should gradually be changed to the oral route. Dietary manipulation is not required in this disorder other than to ensure a normal intake for age in conjunction with the prescribed electrolyte and fluid therapy.

Food allergy in gastroenterology

It is thought that the relatively high incidence of adverse reactions to food proteins seen in infancy is the result of immaturity of local and systemic immune systems, often in association with increased gut permeability to large molecules. One common cause of this is the post-enteritis syndrome where a loss of barrier function and the breakdown of normal immune tolerance follows an enteric infection. Deficiency of immunoglobulin A (IgA), which is involved in the immune defence of mucosal surfaces, is a common associated finding in allergic infants.

Food allergy may broadly be classified as either antibody mediated (e.g. IgE mediated: immediate GI hypersensitivity and oral allergy syndrome) or cell mediated (e.g. T-cell mediated: dietary protein enteropathy, protein induced enterocolitis and

Table 7.4 Gastrointestinal disorders that can be caused by allergy to dietary proteins.

Oral allergy syndrome
Eosinophilic oesophagitis
Eosinophilic gastroenteropathy (food protein induced enterocolitis)
Eosinophilic colitis
Enteropathy
Proctocolitis

proctocolitis) [10]. In some patients both mechanisms can co-exist (eosinophilic gastroenteropathy). Cells and mediators of the immune system such as eosinophils and lymphocytes can be found in biopsies of inflamed sites.

Allergic reactions can affect GI secretion, absorption (with or without mucosal damage) and motility. Interactions between the allergic cells and the mucosal nervous system is important in mediating alterations in secretion and motility. Both interleukin-5 (IL-5), a Th2 produced cytokine, and the chemokine eotaxin have a role in allergic responses that can present as delayed gastric emptying, gastro-oesophageal reflux and constipation [11].

Gastrointestinal conditions caused by allergic reactions to dietary proteins are summarised in Table 7.4. Often in the clinical setting dietary manipulations are used to treat symptoms before any formal investigations are carried out. An algorithm of suggested management is given in Fig. 7.1.

Although the most common foods to cause GI food allergic problems are cow's milk, egg, wheat and soya, any food ingested could be a culprit [12,13]. The current tests available (skin prick tests, patch tests and specific IgE) are of limited use in identifying food allergens causing GI disease. The prescribed exclusion diet is generally based on an underlying family history of atopy (hay fever/allergic rhinitis, asthma, eczema), allergies and organ-specific autoimmunity combined with the age of presentation of symptoms with food intake at that time. Sometimes a number of dietary manipulations need to be tried before the correct dietary restriction for the individual is achieved. In the presence of multiple food allergies, a few foods diet approach or exclusive use of a hypoallergenic feed may be needed with subsequent single food introductions to identify the causative food allergens.

Exclusion diets are difficult to manage at home and are expensive. Selection of suitable patients is important. Use of anti-allergic or anti-inflammatory drugs as a therapeutic alternative to dietary restriction might be considered in situations where the family will not cope with a strict exclusion diet.

When multiple foods are excluded from the diet at one time it is important to challenge sequentially with the excluded foods to identify those the child is reacting to in order to avoid over-restricting the diet.

Exclusion of cow's milk protein

Cow's milk is the most common food to cause a reaction in infants and the incidence of cow's milk protein intolerance (CMPI) or allergy reported in developed countries is between 2% and 3%; 0.5% of breast fed infants are reported to be food allergic or intolerant, reacting to exogenous food proteins secreted into the mother's milk. When an alternative infant formula is tried it is necessary to persist with this formula for a reasonable length of time, observing symptoms carefully, before abandoning it in favour of a different feed. Delayed reactions to dietary proteins can occur several days after their ingestion.

Prognosis is good with remission in approximately 50% of infants by 1 year of age, 75% at 2 years and 90% at 3 years of age. Less than 1% of infants maintain a life-long food allergy [14].

Alternative infant formulas

It is vital that an infant is given a nutritionally complete milk substitute to replace a formula based on cow's milk protein. In breast fed infants the mother's diet needs to be modified by the removal of cow's milk and any other foods allergenic to the infant, ensuring that the maternal diet continues to include adequate amounts of calcium, fluid, energy and protein. It has been found that breast fed infants can be sensitised to multiple allergens, including egg, soy, wheat and fish [15].

Mammalian milks

Mammalian milk is not suitable to be used as an infant feed without modification because of its high

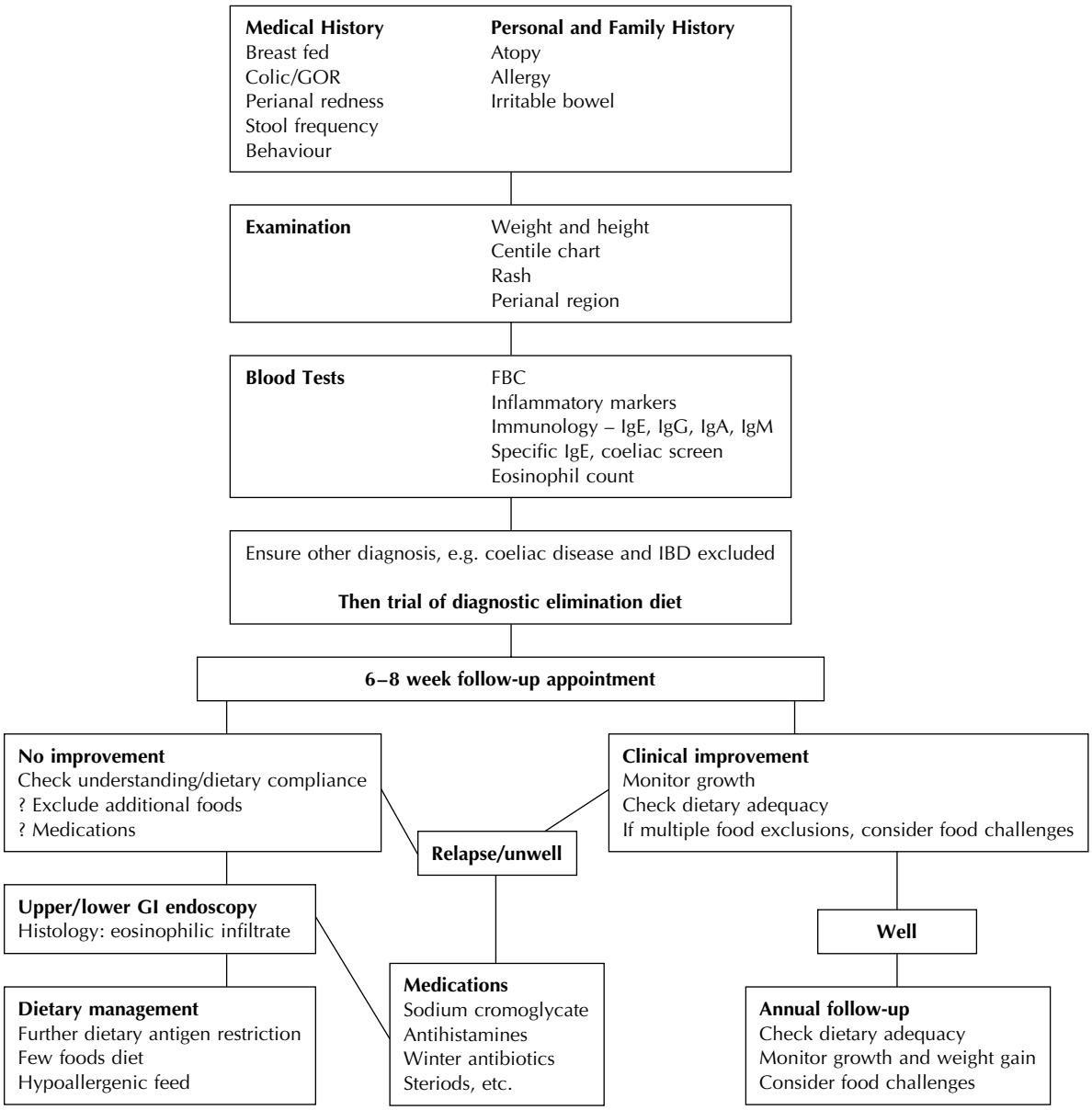

Figure 7.1 Suggested management of food allergy in gastroenterology. FBC, full blood count; GI, gastrointestinal; GOR, gastro-oesophageal reflux; IBD, inflammatory bowel disease; Ig, immunoglobulin.

renal solute load and inadequate vitamin and mineral content. The proteins in goat's and sheep's milks share antigenic cross-reactivity with cow's milk proteins. Infant formulas based on these milks are not recommended for use in GI food intolerances [16]. Infant milks based on goat's milk are not available in the UK.

Soy protein based formulas

A soy protein based formula was used for the first time in 1929 to feed infants with cow's milk protein allergy. Today these feeds are based on a soy protein isolate supplemented with L-methionine to give a suitable amino acid profile for use in infancy.

Table 7.5 Composition of soy infant formula available in the UK, per 100 mL.

Name and manufacturer	Dilution (%)	Energy (kcal)	Energy (kJ)	CHO (g)	Protein (g)	Fat (g)	Osmolality (mOsm/kg H_2O)
InfaSoy (Cow & Gate)	12.7	66	277	6.7	1.8	3.6	200
SMA Wysoy (SMA Nutrition)	13.2	67	280	6.9	1.8	3.6	189
Farley's Soya Formula (Farley's)	13.7	70	294	7.0	2.0	3.8	210
ProSobee (Mead Johnson)	13.0	68	285	6.7	1.8	3.7	180
Isomil (Abbott)	13.1	68	285	6.9 (35% sucrose)	1.8	3.7	250

They are lactose free, with the carbohydrate generally being present as glucose polymer (Table 7.5). The fat is a mixture of vegetable oils that provide long chain fatty acids, including essential fatty acids. Feeding modern soy formulas to infants is associated with normal growth, protein status and bone mineralisation [17].

Use of soy protein in infancy

The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) published a final report on phytoestrogens and health in May 2003 [18]. Phytoestrogens are natural chemicals produced by some edible plants that can mimic or block the action of human oestrogens, although they are much less potent. COT felt that there was evidence of potential risk to the long-term reproductive health of infants from the biological activity of these molecules. Infants during the first 6 months of life are particularly sensitive developmentally and consume large quantities of isoflavones from soya feeds (up to 4 mg/kg/day) compared with an adult using soy products who might ingest 3 mg/day isoflavones.

They concluded that soy based infant formulas should only be fed to infants when indicated clinically. This was echoed by another independent advisory body, the Scientific Advisory Committee on Nutrition (SACN) who also felt that 'the use of soy-based infant formulas is of concern and that there was little evidence to support health benefits over products based on cow's milk protein isolate'.

The Paediatric Group of the British Dietetic Association published a position statement on the use of soya protein in infancy using a pragmatic approach to the advice given by these expert bodies [19]. They recommend that the use of soy formulas in children with atopy or allergy should be discouraged in the first 6 months of life. However, there is still a clinical need to use soy formulas in the following groups of infants as any potential risk is outweighed by the risk of withholding the formula: infants with cow's milk allergy who refuse extensively hydrolysed or elemental formulas, vegan mothers who are unable to breast feed and infants with galactosaemia.

There appears to be less risk to the infant after 6 months of age as the dose of isoflavones per kilogram body weight will be reduced as dependence on formula as a source of nutrition decreases. The infant's potentially vulnerable organ systems are likely to have matured by that age. More research in this area is needed.

Use of soy formulas in gastrointestinal disorders

Soy protein has a very large molecular weight and after digestion can generate a large number of potential allergens. Severe GI reactions to soy protein formula have been described for more than 30 years and include enteropathy, enterocolitis and proctitis. It is suggested that an intestinal mucosa damaged by cow's milk protein allows increased uptake and increased immunologic reaction to soy protein. A reported 60% of infants with cow's milk protein induced enterocolitis are equally sensitive to soy. For these reasons soy protein based formulas are not recommended in the management of cow's milk protein enteropathy or enterocolitis [17].

Older infants with documented IgE-mediated allergy to cow's milk protein can do well on soy

protein based formula [20,21]. In other GI manifestations of possible cow's milk allergy, such as constipation or vomiting, where the mucosa is not damaged, soy feeds can be used. Soy formula has the benefit of being at least half the cost of hydrolysed protein formula and is much more palatable. Soy infant formulas available in the UK are summarised in Table 7.5.

Milk free diet

It is important that carers of infants requiring a cow's milk protein free feed are given appropriate advice to enable them to exclude cow's milk from solids. The following ingredients indicate the presence of cow's milk in a manufactured food: casein, hydrolysed caseinates, whey, hydrolysed whey, lactose, milk solids, non-fat milk solids, butter fat. Parents should be taught to recognise these in lists of ingredients and exclude foods containing them from the diet. A recent change in the law (Directive 2003/89/EC, November 2005) regarding labelling of ingredients now means that products containing milk must be clearly identifiable. Milk free dietary information is summarised in Table 7.6.

Feeds based on protein hydrolysates

Infants with cow's milk allergy and proven or suspected soy intolerance need an alternative type of formula. The allergenicity or antigenicity of a particular protein is a function of the amino acid sequences present and the configuration of the molecule. An epitope is the area of a peptide chain capable of stimulating antibody production. During the manufacture of a hydrolysate the protein is denatured by heat treatment and hydrolysed by proteolytic enzymes leaving small peptides and free amino acids. The enzymes are then inactivated by heat and, along with residual large peptides, are removed by filtration [22].

The proteins used to make a hydrolysate vary and production methods also differ between manufacturers. The profile of peptide chain lengths between different feeds will not be identical, even when the initial protein is the same.

Potential problems with hydrolysate formulas

Despite the rigorous conditions employed in the manufacture of these feeds there are still potential sequential epitopes present that can be recognised by sensitive infants. Extensively hydrolysed protein based feeds vary considerably in their molecular weight profile and hence in their residual allergenic activity. Feeds with peptides of >1500 Da have been demonstrated to have residual allergenic activity [23,24]. The degree of hydrolysis does not predict the immunogenic or the allergenic effects in

Table 7.6 Milk free diet.

Foods permitted	Foods to be excluded	Check ingredients
Milk substitute Vegetable oils Custard made with milk substitute, sorbet	All mammalian milks, cheese, yoghurt, fromage frais, ice cream, butter	Margarines
Meat, fish, eggs, pulses		Sausages, pies, foods in batter or breadcrumbs Baked beans
All grains, dry pasta, flour Bread, most breakfast cereals	Pasta with cheese or milk sauce, milk bread, nan bread Cream cakes, chocolate biscuits	Tinned pasta Bought cakes or biscuits
Fruit and vegetables		Instant mashed potato
Plain crisps, nuts		Flavoured crisps
Sugar, jam, jelly Marmite	Milk chocolate, toffee	Plain chocolate Ketchup, salad dressings, soups
Milk shake syrups and powder Pop, juice, squash	Malted milk drinks	

Table 7.7 Extensively hydrolysed infant feeds available in UK.

Name and manufacturer	Dilution (%)	Energy (kcal)	Energy (kJ)	CHO (g)*	Protein (g)	Fat (g)†	Na^+ (mmol)	K^+ (mmol)	Osmolality (mOsm/kg H_2O)
Casein									
Nutramigen 1 (Mead Johnson)	13.5	68	280	7.5	1.9	3.4	1.4	2.1	290
Nutramigen 2‡ (Mead Johnson)	14.6	72	300	7.8	2.3	3.5	1.6	2.3	342
Pregestimil (Mead Johnson)	13.5	68	280	6.9	1.9	3.8 (55%)	1.3	1.9	330
Whey									
Pepti-Junior (Cow & Gate)	12.8	67	280	6.9 trace lactose	1.8	3.6 (50%)	0.9	1.7	200
Pepti (Cow & Gate)	12.6	66	275	6.8 38% lactose	1.6	3.6	0.8	1.8	240
Pork collagen and soya									
Prejomin (Milupa)	15	75	313	8.6	2.0	3.6	1.4	2.0	193
Pepdite (SHS)	15	71	297	7.8	2.1	3.5 (3%)	1.5	1.5	237
MCT Pepdite (SHS)	15	68	286	8.8	2.0	2.7 (75%)	1.5	1.5	290

SHS, Scientific Hospital Supplies.
* Carbohydrate is present as glucose polymers derived from different sources unless otherwise stated.
† Figures in parenthesis indicate the percentage of fat present as medium chain triglycerides (MCT).
‡ Suitable from 6 months of age.

the recipient infant. It has been recommended that dietary products for treatment of cow's milk protein allergy in infants should be tolerated by at least 90% of infants with documented cow's milk allergy [16]. In instances where an infant is not malnourished and fails to tolerate one hydrolysate formula, a second hydrolysate from a different protein source can be tried.

Table 7.7 shows the composition of extensively hydrolysed infant formulas available in the UK. Feed choice may be influenced by:

- Palatability, which is affected by the presence of bitter peptides. This is particularly important in infants older than 3 months of age
- Co-existing fat malabsorption, where a feed with some of the fat as medium chain triglycerides (MCT) may be indicated
- Cost, some hydrolysates being twice as expensive as others
- Religion and culture, where parents do not wish their children to be given products derived from pork

Feed introduction

Hydrolysate feeds should be introduced slowly to infants with severe GI symptoms as they have a higher osmolality than normal infant formula. Feeds containing a high percentage of MCT should also be introduced gradually to ensure tolerance. The speed of introduction depends on clinical symptoms; a minimum of 12 hours on a half strength feed before the introduction of full strength formula is suggested. If the diarrhoea is very severe then it may be necessary to introduce

Table 7.8 Suggested plan for introducing hydrolysate feeds to older infants fed orally.

Day number	Percentage own feed	Percentage new hydrolysate feed
1	75	25
2	50	50
3	25	75
4	0	100

quarter strength feeds, grading up to full strength feeds over 4 days. If severe diarrhoea is present in an older infant it is preferable to stop all solids while a new feed is being introduced, to assess tolerance.

In an outpatient setting, where symptoms may be less severe, full strength formula can usually be introduced from the outset. In infants older than 6 months there may be an advantage in initially mixing the hydrolysate with their usual formula to slowly introduce the new taste and encourage acceptance. A suggested regimen is shown in Table 7.8. Milk shake flavourings at 2–4% concentration can also be used in this age group if sucrose is not contraindicated.

If an infant refuses to drink the hydrolysate feed a nasogastric tube needs to be passed to ensure adequate feed volumes are taken. Where failure to thrive co-exists, feeds can be fortified in the usual manner by the addition of fat, carbohydrate or an increase in formula concentration. All changes should be made slowly to ensure they are tolerated.

Pepti-Junior and Pepti both have sodium contents similar to standard infant formula which may not be sufficient for an infant with increased stool losses. Low urinary sodium (<20 mmol/L) alongside a normal plasma sodium concentration indicates sodium depletion and supplementation with sodium chloride will be required.

Amino acid based infant formula

Only pure amino acid mixtures are considered to be non-allergenic as there are no peptide chains present to act as epitopes. In infants who fail to tolerate a hydrolysate this is the next logical step, so long as there is not a co-existing fat or carbohydrate intolerance. In these situations a modular feeding approach should be used (see p. 109). At present there is only one such feed for infants in the UK, Neocate (Table 7.9). Studies have shown this to be effective in a number of clinical settings where protein hydrolysates have not been tolerated [13,24]. The sodium content of Neocate is relatively low for infants with chronic diarrhoea and may need further supplementation.

Introduction of solids

Weaning should take place at the recommended age of around 6 months and not before 17 weeks. It is important to ensure that food offered is free of cow's milk protein. Other dietary proteins that are most commonly implicated and may therefore need to be excluded include egg, soy and wheat. In very sensitive infants it may be wise to introduce new foods singly.

Exclusion of soy protein

In conditions where soy intolerance is present in addition to CMPI, foods containing soy and milk protein should be excluded from the diet (Tables 7.6 and 7.10). Vegetable or soy oils and soya lecithin are normally tolerated by individuals sensitive to soy protein and should not need to be excluded from the diet except in severely affected individuals.

Milk, egg, wheat and soy exclusion diets

In conditions where a simple exclusion diet has not worked or where there is a diet history suggestive

Table 7.9 Infant formula based on amino acids available in the UK, per 100 mL.

Name and manufacturer	Dilution (%)	Energy (kcal)	Energy (kJ)	CHO (g)	Protein equivalent (g)	Fat (g)	Na^+ (mmol)	K^+ (mmol)	Osmolality (mOsm/kg H_2O)
Neocate (Scientific Hospital Supplies)	15	71	298	8.1	2.0	3.5 (5% MCT)	0.8	1.6	360

MCT, medium chain triglycerides.

Table 7.10 Foods containing soya protein.

All soy based products including tofu and soy sauce
Texturised vegetable proteins
Breads, biscuits and cakes which contain soy flour
Baby foods containing soy protein
Soy margarines

of multiple food intolerances this dietary regimen may be tried. Families need a lot of help and information about commercial foods to enable them to adhere to this regimen. Suitable wheat free products that are available via the Advisory Committee on Borderline Substances (ACBS) cannot be prescribed for wheat allergy and a separate letter to the GP requesting help is often required. In addition to looking for milk, egg and soy based ingredients on food labels any unidentified starches, rusk and batter also needs to be excluded (Table 7.11).

Suitable feeds for older children

A suitable infant formula should be continued for as long as is nutritionally indicated in children on an exclusion diet and is preferable under the age of 2 years. In situations where a large percentage of the child's nutrition comes from a formula it will either need fortification to meet nutritional requirements or a feed designed for older children should be used. The feeds in Table 7.12 have been designed to meet the requirements of older children requiring hypo-allergenic feeds. Adult feeds based on soy or hydrolysed protein should be used with care in older children and may require modification or vitamin and mineral supplementation.

In children over the age of 2 years consuming a well-balanced diet and tolerating soy protein, supermarket 'adult' liquid soy milks can be given as an alternative to cow's milk. Those with added calcium help to ensure an adequate intake of this

Table 7.11 Milk, egg, wheat and soya free diet.

Foods permitted	Foods to be excluded	Check ingredients
Milk substitute Vegetable oils	All mammalian milks and products, soya milks and soy products, shredded suet Eggs	Margarines
All meat, poultry, fish, shellfish (fresh or frozen), pulses	Meat or fish dishes with pastry, breadcrumbs or batter Tofu, tempeh, soy beans, Quorn	Sausages, beef and vegetarian burgers, hot dogs, ready meals
Rice, rice noodles or pasta, maize corn pasta, cornflour, tapioca, sago, arrowroot, buckwheat, barley, oats, gram flour, potato flour, ground almonds, carob	Wheat, rye and soya flour, spelt flour, wheat bran or germ, semolina, couscous, tabouleh, pancakes, batter, pizza, stuffing mixes, ordinary pasta, e.g. spaghetti	Gluten free bread, cakes, biscuits, pasta; oatcakes
Breakfast cereals made from rice, corn and oats, poppadoms, rice and corn cakes	Wheat based breakfast cereals Bread, crispbreads, crackers, chapatti, croissants, biscuits, cake, cheesecake, instant desserts	
Jelly, custard or blancmange powders, rice, tapioca or sago pudding (made with milk substitute)		Pies, pastries, mousse, trifle, sorbet
Fruit and vegetables	Potato croquettes	Vegetables in dressing, e.g. coleslaw; potato waffles, instant mashed potato
Plain crisps		Flavoured potato crisps
Marmite, Bovril	Mayonnaise, salad cream, soy sauce	Stock cubes, gravy mixes, soups, sauces
Sugar, jam, honey, syrup, plain fruit lollies, milk shake syrup and powder, cocoa powder	Chocolate spread, lemon curd, milk chocolate, instant milk drinks	Plain chocolate, jelly sweets, marshmallows, baking powder, chocolate, malted drinks

Table 7.12 Hydrolysate and amino acid based feeds for older children per 100 mL.

Name	Dilution (%)	Energy (kcal)	Energy (kJ)	CHO* (g)	Protein equivalent (g)	Fat† (g)	Na^+ (mmol)	K^+ (mmol)	Osmolality (mOsm/kg H_2O)
Hydrolysate feeds									
Pepdite 1+ (SHS)	23	100	423	13	3.1	3.9 (35)	2.1	3	465
MCT Pepdite 1+ (SHS)	20	91	380	11.8	2.8	3.6 (75)	1.8	2.6	460
Peptamen Junior (Nestlé)	22	100	418	13.8	3	3.8	2.9	3.5	310
Amino acid feeds									
Neocate Advance§ (unflavoured) (SHS)	25	100	420	14.6	2.5	3.5 (35)	2.6	3.0	610
Neocate Active§** (unflavoured) (SHS)	21	100	420	11.3	2.8	4.8 (4)	1.3	1.5	520
Elemental 028‡§ (unflavoured) (SHS)	20	78	328	14.4	2.0	1.3 (5)	2.6	2.4	496
Elemental 028‡§ Extra (unflavoured) (SHS)	20	89	374	11.8	2.5	3.5 (35)	2.7	2.4	502
Emsogen ‡§¶ (unflavoured) (SHS)	20	88	370	12	2.5	3.3 (83)	2.6	2.4	539

SHS, Scientific Hospital Supplies. * All present as glucose polymer derived from different sources. † Figures in parenthesis show percentage fat present as MCT. ‡ Use with caution for children between 1–5 years. § Flavoured versions of these feeds are also available. ¶ Patients who are receiving a significant proportion of their nutritional requirements from Emsogen may need to supplement their intake of α linolenic acid to meet UK DRVs 1991 [25] and ESPGAN guidelines 1991 (p. 148). ** Neocate Active is designed as a dietary supplement rather than a complete feed.

nutrient. For children intolerant of soy and cow's milk, alternative 'milks' made from oat, rice, nut and pea are available in health food shops and supermarkets; they can be a useful social replacement for cow's milk. Some are fortified with calcium. Calcium supplements (Table 18.14) may be needed to achieve the reference nutrient intake (RNI) [25]. Most of these drinks contain very little protein so high protein foods must be eaten twice a day.

Calcium intakes below recommended intakes have been identified in a number of children limiting cow's milk in their diet, which may affect bone density [26]. One study showed that children aged between 31 and 37 months on milk free diets had significantly lower intakes of energy, fat, protein, calcium, riboflavin and niacin than age-matched controls. Careful monitoring of dietary adequacy with calcium and vitamin supplementation if needed is required [27].

Coeliac disease

This is an autoimmune disease primarily affecting the proximal small intestine characterised by an abnormal small intestinal mucosa and associated with a permanent intolerance to gluten. Coeliac disease (CD) is associated with other autoimmune

disorders and a low IgA. There are at least two prerequisites for developing CD: a genetic predisposition and ingestion of gluten. More than one member of a family may be affected. The incidence was previously estimated to be 1 in 300 in England although a recent study suggested this could be as high as 1 in 100 [28,29]. There is considerable variation in the age of onset and in the mode of presentation, with patients now being diagnosed well into adulthood.

CD is an immunological disorder with local and systemic production of autoantibodies against structural proteins of the small intestine mucosa and other organs, in association with a specific pattern of cell-mediated damage in the small intestine. Anti-tissue transglutaminase (tTG) and anti-endomysial antibodies (the same antibody measured by different methods) are specific markers of CD, although they may not be raised in IgA deficient individuals [30]. These can also be raised in healthy first degree relatives with a normal small intestinal biopsy, perhaps implying that these individuals have a latent form of the disease.

The 'gold standard' for diagnosis remains a small intestinal biopsy demonstrating mucosal damage followed by a clinical response to gluten withdrawal [30,31]. It is important that patients with suspected CD continue on a normal diet until the diagnostic biopsy has been performed and a clear diagnosis made.

Treatment

CD is treated by excluding all dietary sources of gluten, a protein found in wheat, rye and barley. The gluten can be divided into four subclasses: gliadin, glutenins, albumins and globulins. In wheat the injurious constituent is the prolamin fraction of α-gliadin. The equivalent in rye is secalin and in barley hordein. Enzymatic degradation studies have suggested that the damaging fraction is an acidic polypeptide with a molecular weight of <1500 Da.

Gluten free diet

All possible sources of wheat, rye and barley need to be excluded from the diet which needs to be followed for life (Table 7.13). This excludes a number of staple foods such as bread, pasta, biscuits and cakes and parents need support and help in finding suitable substitutes that their child will eat. Wheat flour is commonly used in processed foods as a binding agent, filler or carrier for flavourings and spices. Recent testing using a more sensitive analysis method has shown that some breakfast cereals containing malt flavourings derived from barley exceed the accepted threshold allowed by the international Codex Standard and are no longer considered suitable for inclusion in the gluten free diet. Parents and children with CD need to be taught to

Table 7.13 Gluten free diet.

Foods permitted	Foods to avoid	Check ingredients
Milk, butter, cream, cheese		Cheese spreads, yoghurts, custard
Meat, fish, eggs, pulses	Products with pastry, thickened gravies and sauces, breadcrumbs, batter	Sausages, tinned meats
Rice, corn (maize), buckwheat, millet, tapioca, soya, gram flour, arrowroot	Wheat, rye, barley, bread, crumpets, cakes, biscuits, crackers, crispbread, chapattis, nan bread, pasta, noodles, semolina, couscous	Oats*
Special gluten free flours, breads, biscuits and pasta	Wheat based cereals, e.g. Weetabix, Shredded Wheat	Corn and rice based cereals
Vegetables, potato, fruit and nuts	Potato croquettes	Flavoured potato crisps, dry roasted nuts
Sugar, jam, honey, some chocolates	Liquorice	Filled chocolates, boiled sweets
Tea, coffee, drinking chocolate, fizzy drinks, juice, squash	Malted milk drinks, e.g. Horlicks and Ovaltine Barley water, beer	

* Exclusion may be necessary.

identify sources of the offending cereals in lists of food ingredients. A recent change to the food labelling legislation (Directive 2003/89/EC, November 2005) means that all foods containing gluten or wheat must be clearly labelled; exemptions to ingredient listing of compound ingredients have largely been abolished.

Children tend to be the highest consumers of savoury snack foods and processed foods which need to be excluded on this diet. The Food and Drink Directory produced annually by Coeliac UK and updated monthly on their website using data from supermarkets and manufacturers is an important resource for all individuals with CD. Increased variety of foods allowed will improve patient compliance. Young children should be taught to check with parents before eating foods outside the home or offered by siblings or friends. Where possible meals should be prepared that are suitable for the whole family so that the child does not feel different. Children's parties are a source of concern to parents and the coeliac child should be sent with suitable foods of their own to eat.

Commercially produced gluten free foods

A large number of proprietary gluten free foods are available, some based on wheat starch. In ordinary manufactured foods containing wheat starch the latter is not pure enough to be included in a gluten free diet. However, specially manufactured foods that comply with the International Gluten Free Standard up to 200 ppm (WHO Codex Alimentarius 1981) are suitable for inclusion in the diets of most people with CD. A number of staple food items have been passed as prescribable for patients with CD by ACBS, while the more luxurious items such as fruit cakes can be purchased via pharmacies or health food shops. Some supermarkets produce their own ranges of gluten free foods.

A prescribing guide for the gluten free diet has been produced by BSPGHAN (British Society of Paediatric Gastroenterology, Hepatology and Nutrition) to define the minimum monthly gluten free food prescription requirements for children and adults with CD [32]. Good dietary compliance is aided by the ease with which patients can obtain suitable amounts of gluten free foods on prescription. A large number of companies produce such foods and a complete list can be found in the *British National Formulary* (BNF) or in Coeliac UK's Food and Drink Directory. Products vary and patients should be encouraged to try different food items. Some of the larger companies will send newly diagnosed patients trial packs of their own products on application.

Oats

The inclusion of oats in the gluten free diet remains controversial. It is unclear whether the prolamin in oats, called avenin, contains the amino acid sequences that trigger the histological changes in the small intestinal mucosa. The quantity of avenin in oats is much less than the prolamins in other cereals, thus a larger quantity of the product may be required to produce an effect. Problems with earlier studies included small patient numbers, insensitive functional tests and small intestinal biopsies which were often difficult to interpret [33]. Coeliac UK's Medical Advisory Council published interim guidelines stating that moderate amounts of oats may be consumed by most adult coeliacs without risk, although the situation is less clear with children. Highly sensitised coeliacs should at present not be allowed oats and patients should be carefully followed up [34].

Two papers purport to show the safety of oats when ingested by adults and children with CD. The adult data showed no harm at 5 years, yet a significant number (33%) of the original subjects did not include oats in their diet during the follow-up period [35]. The randomised double blind paediatric study had a high number of withdrawals in both the group that ate oats (26%) and those whose diet remained free of oats (11%). At the end of the study the children consuming oats were taking smaller amounts than prescribed which, in some, may have resulted in too little avenin to cause an effect [36].

A further complicating factor is that oats can be contaminated with wheat at various stages of production: in fields, transportation, storage, milling and processing. Care should therefore be taken to avoid contaminated sources. The author's current practice is to initially advise avoidance of oats at the start of the gluten free diet but to review this at a later date once the patient is responding to the diet. Oat products are now included in an appendix to Coeliac UK's annual food list.

Bone health

One of the main complications of CD in adults is reduced bone mineral density leading to osteoporosis. It is unclear if this is caused by calcium malabsorption for prolonged periods prior to diagnosis. Studies in children found that while the bone mineral content of coeliacs was significantly lower than control subjects at diagnosis, after 1 year on a gluten free diet it had returned to normal. The calcium intake of the children was not assessed during this time [37]. Although there are no formal recommendations it would appear sensible to ensure that children's intake is at least equal to the RNI for calcium for their age [25]. Some gluten free products are fortified with calcium.

Coeliac UK

This is an independent registered charity with free membership which all parents of children with CD should be encouraged to join. The society acts as an invaluable resource on all aspects of management of the gluten free diet including topics as diverse as eating out to travelling abroad. It also produces many helpful publications: www.coeliac.co.uk.

Gluten challenge

ESPGHAN guidelines for the diagnosis of CD are currently being reviewed to include up-to-date serology testing. The 1990 guidelines state that gluten challenge is only necessary when there is some doubt at the time of initial diagnosis, for instance if the initial biopsy was atypical or if a gluten free diet was started before the biopsy with a clinical response [31]. For challenge purposes gluten can be introduced into the diet in two forms: either as gluten powder that can be mixed in foods such as yoghurt, or as gluten containing foods. Both need to be given daily in sufficient amounts to ensure an adequate challenge. Two slices of bread a day for older children has been suggested by one author [31]. The author's practice has been to give the children a normal diet for the duration of the challenge. Parents are often anxious that the inclusion of normal foods in the diet will make returning to gluten free diet difficult if the diagnosis of CD is confirmed. Reassurance is required and an explanation of the procedure to the child is very important in ensuring its success.

Associated food intolerances

Although a secondary disaccharidase deficiency can be demonstrated at the time of diagnosis it is rarely necessary to exclude lactose from the diet of a newly diagnosed individual with CD. However, some infants seem to be intolerant of cow's milk protein and benefit from a temporary dietary exclusion in addition to avoidance of gluten. They should be rechallenged with cow's milk 2–3 months after the commencement of the gluten free diet.

If patients remain symptomatic on a strict gluten free diet it may be necessary to exclude products containing traces of gluten such as gluten free wheat starch and all foods containing malt extract and flavouring. Patients responding to such dietary manipulations are described as super-sensitive.

Carbohydrate intolerances

Sugar malabsorption increases the osmotic load of GI fluid, draws water into the small intestine and stimulates peristalsis, resulting in diarrhoea. The severity depends on the quantity of ingested carbohydrate, the metabolic activity of colonic bacteria (which is reduced after antibiotic therapy) and the absorptive capacity of the colon for water and short chain fatty acids.

The infant is at a disadvantage compared with the adult as the small intestine is shorter and the reserve capacity of the colon to absorb luminal fluids is reduced. Because of a faster gut transit time there is less time for alternative paths of carbohydrate digestion to be effective. The undigested sugar is either excreted unchanged or is fermented by bacteria in the colon to short chain fatty acids and lactic acid.

Disaccharidase deficiencies

In the brush border of the small intestine there are four disaccharidase enzymes, with the highest level

Table 7.14 Brush border enzyme activity in the small intestine.

Enzyme	Substrate	Product
Sucrase-isomaltase (accounts for 80% maltase activity)	Sucrose α1–6 glucosidic bonds in starch molecule (approx. 25%) Isomaltose Maltose Maltotriose	Glucose Fructose
Maltase-glucoamylase (accounts for 20% maltase activity)	Maltose Maltotriose Starch	Glucose
Lactase	Lactose	Glucose Galactose
Trehelase	Trehalose	Glucose

Table 7.15 Low sucrose, low starch solids (<1 g/100 g).

Protein	Meat, poultry, egg*, fish
Fats	Margarine, butter, lard, vegetable oils
Vegetables	Most vegetables *except* potato, parsnip, carrot, peas, onion, sweet potato, sweetcorn, beetroot [39]
Fruits	Initially use fruits with <1 g sucrose per 100 g fruit (Table 7.16) Most fruits contain negligible amounts of starch
Milk	Breast milk, infant formula (free of glucose polymer and sucrose) Cow's milk, unsweetened natural yoghurt, cream
Others	Marmite, Bovril, vinegar, salt, pepper, herbs, spices, 1–2 teaspoons of tomato purée can be used in cooking, gelatine, essences and food colourings, sugar free jelly, sugar free drinks, fructose, glucose

* Soft eggs should not be given to babies under 1 year of age.

of activity occurring in the jejunum (Table 7.14). Deficiencies of these enzymes can be primary in nature resulting from a congenital enzyme defect or can be secondary to some other GI insult.

Congenital sucrase-isomaltase deficiency

Congenital sucrase-isomaltase deficiency (CSID) is an autosomal recessively inherited disease which is a rare, but frequently misdiagnosed, cause of chronic diarrhoea in infants and children. There is wide phenotypic variation. All CSID patients have an absence of intestinal sucrase activity; however, isomaltase activity varies from very little to almost normal. Although considered rare, the prevalence of CSID may have been underestimated and it is likely that the disease remains undiagnosed in numerous patients with a history of chronic diarrhoea, some of whom are diagnosed with CSID as adults.

While being breast fed or given a normal infant formula the infant remains asymptomatic and thrives. The introduction into the diet of starch or sucrose in weaning foods, or the change in formula to one containing sucrose or starch (found in pre-thickened formulas), initiates symptoms. The clinical presentation of CSID is very variable. Chronic watery diarrhoea and failure to thrive are common findings in infants and toddlers. A delay in the diagnosis may be related to the empirical institution of a low sucrose diet by parents, which controls symptoms. Some children attain relatively normal growth with chronic symptoms of intermittent diarrhoea, bloating and abdominal cramps before diagnosis. In older children such symptoms may result in the diagnosis of irritable bowel syndrome.

One retrospective study suggests that a change in infant feeding practices in the last 20 years has resulted in the delayed introduction and decreased ingestion of sucrose and isomaltose in infancy. This has modified the course and the symptoms of the disease resulting in milder forms of chronic diarrhoea which may not start until a few weeks after the introduction of solids compared with a more acute onset of symptoms previously observed [38].

Treatment

In the first year of life this usually requires the elimination of sucrose from the diet. Starch is excluded initially and then introduced to tolerance (Table 7.15). The lactose in normal infant formula, breast milk and cow's milk is tolerated.

Care needs to be taken to ensure an adequate vitamin intake and it may be beneficial to continue an infant formula after 1 year of age. All medications should be sucrose free; a suitable complete carbohydrate free vitamin supplement is Ketovite liquid and tablets.

With increasing age the tolerance of starch and the lower sucrose containing foods should improve until, by the age of 2–3 years, the restriction of

Table 7.16 Sucrose content of some common fruits (per 100 g edible portion) [39].

<1 g sucrose	<3 g sucrose	<5 g sucrose
Bilberries, blackcurrants, cherries, damsons, gooseberries, grapes, lemons, loganberries, lychees, melon (except Gallia), pears, raisins, raspberries, redcurrants, rhubarb,strawberries, sultanas	Gallia melon, grapefruit, kiwi fruit, passion fruit, plums	Apples, apricots, oranges, clementines, satsumas

starch should no longer be needed. Tolerance can be titrated against dietary intake; if the capacity to absorb carbohydrate is exceeded this will cause osmotic diarrhoea or a recurrence of abdominal symptoms. Reducing the carbohydrate to the previously tolerated level will result in normal stool production. The sucrose content of fruits is shown in Table 7.16. Fruits containing higher amounts of sucrose can be added to the diet according to tolerance. If children have problems tolerating starch in reasonable quantities, soy flour can be used in recipes to replace wheat flour as it only contains 15 g starch per 100 g compared with 75 g per 100 g in wheat flour. Parents need reassurance that occasional dietary indiscretions will not cause long term problems.

Newly diagnosed older children should initially be advised to avoid dietary sources of sucrose only. If this does not lead to a prompt improvement in symptoms then the starch content of the diet can be reduced, particularly those foods with a high amylopectin content such as wheat and potatoes. Advice needs to be given to increase energy from protein and fat to replace the loss in dietary energy from reducing carbohydrate foods. Glucose tablets and Lucozade may be included in the diet. There is an international support group that tracks children with CSID and also provides further information on this disorder: www.csidinfo.com.

Enzyme substitution therapy

Sacrosidase, a liquid preparation containing high concentrations of yeast derived invertase (sucrase), has been used with good results and is available on prescription (Sucraid, Orphan Medical Inc). It is stable if refrigerated and tasteless when mixed with water. This formulation has also been shown to be resistant to acidic pH. Degradation by intragastric pepsin is buffered by taking the enzyme with protein foods. Unlike human intestinal sucrase-isomaltase, it has no activity on oligosaccharides containing α1–6 glucosidic bonds.

A controlled, double blind trial of sacrosidase in 14 patients with CSID showed symptoms of diarrhoea, abdominal cramps and bloating were prevented or ameliorated in patients consuming a sucrose containing diet. The dosage recommended is 1 mL with each meal in patients weighing <15 kg, and 2 mL for those weighing >15 kg. This allows the consumption of a more normal diet by children with CSID and decreases the high incidence of chronic gastrointestinal complaints seen in this condition [40,41].

Lactase deficiency

Congenital lactase deficiency is very rare, the largest group of patients being found in Finland. Severe diarrhoea starts during the first days of life, resulting in dehydration and malnutrition, and resolves when either breast milk or normal formula are ceased and a lactose free formula is given (Table 7.3).

Primary adult type hypolactasia is found in a large proportion of the world's populations. Lactase levels are normal during infancy but decline to about 5–10% of the level at birth during childhood and adolescence. These population groups are common in East and South-East Asia, tropical Africa and native Americans and Australians. The age of onset of symptoms varies but is generally about 3 years or later, and only if a diet containing lactose is offered. In the majority of Europeans lactase levels remain high and this pattern of a declining tolerance of lactose with age is not seen.

In other ethnic groups with this problem a moderate reduction of dietary lactose will be sufficient, using either lactose reduced milks available from the supermarket or soy milks. It is important to ensure that children meet their requirements for calcium.

Secondary disaccharidase deficiency

Carbohydrate malabsorption can occur secondary to any insult causing damage to the GI mucosa.

Table 7.17 Composition of Galactomin 19 per 100 mL.

	Dilution (%)	Energy (kcal)	Energy (kJ)	Protein (g)	CHO (g)	Fat (g)	Na^+ (mmol)	K^+ (mmol)	Osmolality (mOsm/kg H_2O)
Galactomin 19 Formula (Scientific Hospital Supplies)	12.9	69	288	1.9	6.4	4.0	0.9	1.5	407

This can present at any age, with onset of symptoms occurring shortly after the primary injury, for instance in cow's milk protein enteropathy, rotavirus infection, Crohn's disease, short gut syndrome and immunodeficiency syndromes.

Lactase deficiency is the most common secondary enzyme deficiency to be seen, probably because it has a lower activity than the other intestinal enzymes and is located on the distal end of the villous tip making it more susceptible to damage. However, a secondary sucrase-isomaltase deficiency can also occur.

Treatment

Treatment is to eliminate the offending carbohydrates and treat the primary disorder causing the mucosal damage. Clinical course depends on the underlying disease but studies in infants with rotavirus infections have shown an incidence of 30–50% lactose intolerance which recovers 2–4 weeks after the infection.

Children requiring a lactose free formula and diet can use either lactose free, cow's milk protein based formula (Table 7.3) or soy formula (Table 7.5). A milk free diet (Table 7.6) is necessary although mature cheese can be included. Medications need to be checked as these can contain lactose as a filler.

Monosaccharide malabsorption: glucose–galactose malabsorption

This is an extremely rare congenital disorder resulting from a selective defect in the intestinal glucose and galactose/sodium co-transport system in the brush border membrane. Glucose, galactose, lactose, sucrose, glucose polymers and starch are all contraindicated in this disorder. It presents in the neonatal period with the onset of severe, watery, acidic diarrhoea leading to dehydration and metabolic acidosis. It is a heterogeneous condition in its expression and older children seem to have considerable variation in their tolerance of the offending carbohydrates.

Treatment

Initial intravenous rehydration is required. The use of ORS, all of which are glucose or starch based, is contraindicated. A fructose based complete infant formula, Galactomin 19, should be introduced slowly, initially as quarter and half strength formula with intravenous carbohydrate and electrolyte support, to avoid metabolic acidosis (Table 7.17).

Once the infant is established on feeds and gaining weight, it is important to discuss with the child's doctor a suitable protocol for oral rehydration should the child become unwell. Plain water or a 2–4% fructose solution can be given, but this does not have the same effect on water absorption as ORS. In severe infectious diarrhoea the infant may need intravenous fluids.

Fructose is available on prescription for this condition and can be used to sweeten foods for older children and as an additional energy source. It is important to ensure that all medicines are carbohydrate free.

Introduction of solids

Initially weaning solids should contain minimal amounts of starch, sucrose, lactose or glucose (Table 7.18). Manufactured baby foods are not suitable and it is necessary for weaning solids to be prepared at home. All foods should be cooked without salt and initially blended to a very smooth texture. To save time parents can prepare foods in advance and freeze in clean ice cube trays. Recipes are available from the author for egg custard sweetened with fructose and for fructose meringues.

With increasing age children gradually begin to absorb more of the offending carbohydrates due to

Table 7.18 Foods allowed in children with glucose–galactose malabsorption (<1 g glucose and galactose per 100 g).*

Protein	Meat, poultry, egg,† fish
Fats	Margarine, butter, lard, vegetable oils
Vegetables	Ackee (canned), asparagus, bamboo shoots, beansprouts (canned only), broccoli, celery, cucumber, endive, fennel, globe artichoke, lettuce, marrow, mushrooms, spinach, spring greens, steamed tofu, watercress, preserved vine leaves
Fruits	Avocado pear, rhubarb, lemon juice
Milk substitute	Galactomin 19 Formula
Others	Marmite, Bovril, vinegar, salt, pepper, herbs, spices, 1–2 teaspoons of tomato purée can be used in cooking, gelatine, essences and food colourings, sugar free jelly, sugar free drinks, fructose

* The lists of foods have been compiled calculating the amount of glucose and galactose as: g starch + g glucose + g lactose + 0.5 g sucrose [39].
† Soft eggs should not be given to babies under 1 year of age.

colonic salvage. The foods in Table 7.19 are grouped to allow a gradual increase in the amount of glucose and galactose in the diet. These lists can be used as a guide by parents. Small amounts of new foods can be introduced cautiously and increased as tolerated. Too much of these foods will exceed the individual's tolerance and cause diarrhoea. In this situation the child should return to the diet previously well tolerated and try introductions again a few months later.

Infants and children are very dependent on Galactomin 19 to meet their requirements for energy and parents should be encouraged to continue this formula for as long as possible. It can also be useful for older children entering adolescence who find it difficult to meet their increased energy requirements from eating a low starch diet. If sufficient formula is taken a vitamin supplement should not be needed.

Fat malabsorption

Intestinal lymphangiectasia

This is characterised by dilated enteric lymphatic vessels which rupture and leak lymphatic fluid into the gut, leading to protein loss. The presentation is variable but diarrhoea and hypoproteinaemic oedema are commonly seen. Failure to thrive can

Table 7.19 Glucose and galactose content of foods (per 100 g edible portion [39]).

1–2 g glucose + galactose	2–3 g glucose + galactose	3–5 g glucose + galactose
Protein Quorn, all 'hard' cheeses, cream cheese, brie, camembert		
Vegetables Aubergine, beans – french and runner, brussel sprouts, cabbage, cauliflower, celeriac, courgettes, gherkins (pickled), leeks, okra, onions (boiled), green peppers, radish, spring onions, swede, tomatoes (including tinned), turnip	Carrots	Sugar snap peas, butternut squash, mange tout
Fruits Gooseberries, redcurrants	Apples – cooking (sweeten with fructose or artificial sweetener), blackberries, loganberries, melon (all types), pears, raspberries, strawberries	Apricots, blackcurrants, cherries, clementines, peaches, pineapple, grapefruit, nectarines, oranges, satsumas, tangerines
Other Ordinary mayonnaise (retail) – not reduced calorie	Double cream	Whipping cream

also be a significant problem. Children usually present in the first 2 years of life although cases diagnosed as late as 15 years of age are documented [42]. The diagnosis is definitively established by a small intestinal biopsy demonstrating the characteristic lymphatic abnormality although, as the lesion is a patchy one, negative biopsy does not exclude the diagnosis [43]. Development of a video capsule that passes through the small intestine will aid diagnosis in this disorder.

Treatment

Treatment is by diet unless the lesion is localised enough to allow surgical excision of the involved part of the intestine. A reduced long chain triglyceride (LCT) diet is needed to control symptoms. This reduces the volume of intestinal lymphatic fluid and the pressure within the lacteals. It is recommended that the amount of LCT should be restricted to 5–10 g/day [43]. A very high protein intake may also be needed to maintain plasma levels of albumin. Intakes of protein as high as 6 g/kg/day with sufficient energy to ensure its proper utilisation have been suggested, although these guidelines are not evidence based. If the intestinal leakage can be stopped by reducing the lymphatic flow then such a high intake of protein should not be required. Enteric protein loss can be monitored by measuring faecal α_1-antitrypsin levels. MCT can be used as an energy source and to increase the palatability of the diet as these are absorbed directly into the portal system and not via the lymphatics.

Suitable feeds in infancy and early childhood are Monogen, MCT Step 1 or Caprilon, the first two being preferable because of their higher protein and energy content and lower LCT content (Table 7.20). If additional protein needs to be given to maintain plasma albumin levels, this can be added to a complete feed (e.g. or Vitapro). The fat and electrolyte content of these products should be calculated in addition to the quantities supplied by the feed.

Minimal fat diet

Minimal fat weaning solids should initially be introduced and gradually expanded aiming to keep the total LCT intake below 10 g/day, certainly in the first 2 years of life. Details of minimal fat diets are given elsewhere (see pp. 251, 427). Attention needs to be given to protein intake and extra very low fat, high protein foods may be included.

As the problem is life-long it is necessary to continue dietary restrictions, certainly until the end of the pubertal growth spurt, although maintaining such a low intake of fat becomes increasingly difficult as the child becomes older. There is no information about the degree of fat restriction required in older children and some relaxation of the diet should be possible so long as symptoms are controlled and growth is adequate. Nutritional supplements such as Build Up made with skimmed milk, Fortijuce, Enlive Plus and Provide Xtra may be useful to ensure adequate protein intake in older children (see Table 11.3).

As the dietary restrictions are long term it is particularly important to ensure that the recommended amounts of essential fatty acids (EFAs) are included in the diet once the volume of complete infant formula is reduced. Walnut oil provides the most concentrated source of EFAs and can be given as a measured amount as a dietary supplement daily. Recommended amounts would be at least 0.1 mL per 56 kcal (234 kJ) provided from foods and drinks not supplemented with EFAs (see p. 427); however, there are no data as to how well this is

Table 7.20 Composition of minimal fat, cow's milk protein based infant formulas per 100 mL.

	Dilution (%)	Energy (kcal)	Energy (kJ)	Protein (g)	CHO (g)	Fat (g)	Na^+ (mmol)	K^+ (mmol)	Osmolality (mOsm/kg H_2O)
Monogen (Scientific Hospital Supplies)	17.5	74	310	2.0	12.0	2.0 (90% MCT)	1.5	1.6	280
MCT Step 1 (Vitaflo)	17.5	7.4	310	2.1	12.0	2.1 (90% MCT)	1.4	1.6	238
Caprilon (Scientific Hospital Supplies)	12.7	66	275	1.5	7.0 (12% lactose)	3.6 (75% MCT)	0.8	1.7	233

MCT, medium chain triglycerides.

absorbed in this disorder. It may be prudent to give double the normal amount of walnut oil as a divided dose mixed with food or as a medicine. This needs to be included in the daily fat allowance.

Fat-soluble vitamin supplements (A, D, E) to meet at least the RNI for age should be given separately. If the above nutritional supplements are used they are fortified with these vitamins so separate vitamin supplements may not be required. Blood levels should be monitored at outpatient clinics.

Neonatal enteropathies and protracted diarrhoea

The causes of protracted diarrhoea in the first few months of life are mostly post-infectious enteropathies and food allergic enteropathies. Rare, and usually early onset, causes include microvillous inclusion disease, tufting enteropathy and auto-immune enteropathy [44]. Congenital glucose–galactose malabsorption, congenital chloride losing diarrhoea and congenital sodium losing diarrhoea will also manifest from birth, although villus morphology is normal in these babies.

Microvillous inclusion disease is a severe and intractable enteropathy that requires parenteral nutrition (PN) for fluid and nutritional maintenance. The genetic basis is unknown and for some reason it does not manifest *in utero* with hydramnios (as a result of intrauterine diarrhoea), but becomes apparent usually in the first few postnatal days. A late onset presentation is also recognised. Microvillous atrophy is almost invariably fatal without the intervention of PN or intestinal transplantation. Early onset syndromes are characterised by secretory diarrhoea (typically 200–250 mL/kg/day) and intolerance of any oral nutrition. Many babies in this group have early onset cholestatic liver disease.

Tufting and auto-immune enteropathies have a better outcome. Infants require PN support, but there appears to be a range of severity in these disorders with some children becoming less dependent on, and even stopping PN as they progress through childhood. The enteral management of tufting enteropathy is limited to the exclusion of major food allergens if there is concurrent inflammation in the gut biopsies. Auto-immune enteropathies are usually treated with immunosuppression, hypoallergenic feeds and dietary exclusion, but where there is evidence of an underlying primary immunodeficiency haematopoietic stem cell transplantation might be considered.

Modular feeds for use in intractable diarrhoea or short gut syndrome

Intractable diarrhoea can be defined as chronic diarrhoea in the absence of bacterial pathogens of >2 weeks' duration, together with failure to gain weight. Some infants with severe enteropathy or short gut syndrome fail to respond to feed manipulation using protein hydrolysates or amino acid based formulas as previously described and a modular feed becomes the feed of choice [45]. This allows individual manipulation of ingredients resulting in a tailor-made feed for a child. Careful assessment and monitoring is important to prevent nutritional deficiencies and to evaluate the response to feed manipulation. This approach can also assist in the diagnosis of the underlying problem.

Theories as to why modular feeds work include:

- The omission of an ingredient that is poorly tolerated
- The very slow mode of introduction which allows time for gut adaptation to take place
- The delay in adding fat to the feed (traditionally the last ingredient to be added) which may alter the inflammatory response in the gut

None of these theories have been proven but clinical experience has demonstrated the approach can be effective.

Feed ingredients

Some of the possible choices of feed ingredients and their advantages and disadvantages are listed in Tables 7.21–7.24. Before starting there needs to be a discussion with the medical staff regarding the appropriate feed composition for the individual baby and to establish good medical support for the dietitian managing the baby's nutrition. The aim is to produce a feed that is well tolerated and meets the infant's nutritional requirements. The following parameters need to be considered:

- Total energy content and appropriate energy ratio from fat and carbohydrate
- Protein, both type used and quantity

Table 7.21 Protein sources for use in modular feeds.

Product	Protein type	Suggested dilution (g/100 mL)*	Protein equivalent (g/100 mL)	ACBS prescribable	Comments
Hydrolysed Whey Protein/ Maltodextrin Mixture (SHS)	Hydrolysed whey	4	2	N	At this dilution: 1.5 g glucose polymer 0.8 mmol Na + 0.6 mmol K
Pepdite Module (Code 767) (SHS)	Hydrolysed pork and soya	2.5	2.2	N	At this dilution: 1 mmol Na + 0.4 mmol K
Complete Amino Acid Mix (SHS)	L-amino acids	2.5	2.0	N	Amino acids increase feed osmolality No electrolytes

ACBS, Advisory Committee on Borderline Substances.
* This is a suggested dilution only. Quantities can be varied according to the desired protein intake, age of child and feed tolerance.

Table 7.22 Carbohydrate sources for use in modular feeds.

Product	Suggested concentration (g/100 mL)	ACBS prescribable	Comments
Glucose polymer,* e.g. Maxijul (SHS), Polycal (Nutricia)	10–12	Y	Carbohydrate of choice as has the lowest osmolality
Glucose	7–8	Y	Use when glucose polymer intolerance is present. A combination of the two monosaccharides can be used to utilise two transport mechanisms
Fructose	7–8	Y	Monosaccharides will increase final feed osmolality

ACBS, Advisory Committee on Borderline Substances.
* Intolerance to glucose polymers has been documented in the literature [46]. This may be caused by a deficiency of pancreatic amylase or of the disaccharidase glucoamylase. Monosaccharides become the carbohydrates of choice in this situation. It may be possible to use sucrose as an alternative carbohydrate.

Table 7.23 Fat sources for use in modular feeds.

Product	Suggested concentration (g/100 mL*)	Comments
Calogen (canola, sunflower oil emulsion) (SHS)	6–10	Contains linoleic acid (C18 : 2) + α-linolenic acid (C18 : 3)
Liquigen (MCT emulsion) (SHS)	4–8	MCT increases feed osmolality. Does not contain EFAs
Vegetable oils, e.g. olive, sunflower†	3–5	Not water miscible. An emulsion can be prepared by mixing 50 mL oil with 50 mL water and liquidising with 1–2 g gum acacia

EFA, essential fatty acids; MCT, medium chain triglycerides.
* The amount of fat used will depend on tolerance.
† These ingredients are not Advisory Committee on Borderline Substances (ACBS) listed.

Table 7.24 Vitamins and mineral supplements for use in modular feeds.

Metabolic Mineral Mixture (SHS) + Ketovites 5 mL liquid + 3 tablets (Paines and Byrne)	Provide electrolytes. Does not contain selenium or chromium. Vitamins should be given separately Recommended dose of MMM is 1 g/100 mL up to a maximum 8 g dose. Doses >1.5 g/kg body weight/day may result in excessive electrolyte intake
Paediatric Seravit (SHS)	Contains glucose polymer which may be contraindicated. Does not contain electrolytes

- Essential fatty acid intake
- Full vitamin and mineral supplementation, including trace elements
- Suitable electrolyte concentrations
- Feed osmolality

Practical details

- Accurate feed calculation and measurement of ingredients is required to make the necessary small daily feed alterations. Scoop measurements are not accurate enough and ingredients should be weighed on electronic scales.
- Infants with protracted diarrhoea or short gut syndrome will tolerate frequent small bolus feeds given 1–2 hourly, or continuous feeds via a nasogastric tube, better than larger bolus feeds.
- Attention needs to be given to the combination of ingredients as these will affect the feed osmolality. The smaller the molecular size the greater the osmotic effect. Most hospital chemical pathology laboratories will analyse feed osmolality on request.
- Infants requiring a modular feeding approach will have high requirements for all nutrients.
- Paediatric Seravit and Metabolic Mineral Mixture used in conjunction with a fat emulsion, such as Calogen or Liquigen, causes the fat to separate out. For feeds given as a continuous infusion it is recommended that these products are administered separately.

Introduction of modular feeds

Depending on the clinical situation feeds are often introduced very slowly and the concentration of the individual components are gradually increased (Table 7.25). Occasionally, if an infant is already taking a full strength complete feed such as Neocate and the necessary dietary change is to use a modular feed with, say, the same profile as

Table 7.25 Example of slow introduction of a modular feed based on complete amino acid mix.

Time	Complete amino acid mix	NaCl/KCl	Maxijul	Liquigen*	Volume
Day 1–3	1/2 strength increasing to full strength	Full strength	4%	Nil	As prescribed*
Day 4–9	Full strength	Full strength	Increase in 1% increments daily to total of 10%	Nil	No change
Day 10–15	Full strength	Full strength	10%	Add in 1% increments to 6%	No change
Day 16†	Full strength	Full strength	10%	6%	Increase volume

A vitamin and mineral supplement such as Paediatric Seravit is required to make a complete feed. This should be administered separately if the feed contains a fat emulsion and is being fed continuously.
* Liquigen does not contain EFAs. This feed needs walnut oil given separately.
† If the child is having total parenteral nutrition (TPN) 10–20 mL/kg/day of feed should be given until a full energy feed is established, after which the feed volume can be increased in 2–5 mL/kg daily increments and the parenteral nutrition reduced in tandem.

Neocate with the exception of MCT as the source of fat rather than the usual LCT, then the modular feed may be started at full strength rather than going through this slow increase in concentration.

- Before starting a modular feed it is necessary to assess the infant's symptoms and current nutritional support. If PN is not available feeds should be introduced more rapidly to prevent long periods of inadequate nutrition.
- In the absence of intravenous glucose, the carbohydrate content of the feed should never be less than 4 g/100 mL because of the risk of hypoglycaemia. A higher percentage of energy from fat than from carbohydrate may result in excessive ketone production.
- An example of the slow introduction of an amino acid based modular feed (Tables 7.25 and 7.26) can be applied to other protein sources. Suggested incremental changes can take place every 24 hours. If well tolerated this process can be accelerated.
- The infant's response to each change of feed should be assessed daily before making any further alterations. Where possible making more than one alteration at a time should be avoided.

Preparing and teaching for home

After a period of time on a modular feed it may be worth trying a nutritionally complete feed again to see if this is now tolerated. The formula nearest in composition to the modular feed should be chosen and challenged slowly. If this is not possible, the aim should be to simplify feed ingredients as much as possible for home.

- Ingredients need to be converted into scoop measurements, using the minimum number of different scoops possible to avoid confusion, or scales can be used that measure in 1 g increments.
- A 24-hour recipe should be given to reduce inaccuracies in feed reconstitution, paying due care to issues of hygiene and refrigeration of feed until it is used. It is important to demonstrate the method for making the feed to the infant's carers on at least one occasion before discharge.
- Consideration should be given to providing a laminated recipe and wipe off pen for home use.
- Not all the suggested ingredients for modular feeds are ACBS listed. A separate letter to the child's general practitioner will be needed to arrange a supply of the product. A supply of these items may need to be given from the hospital.

Introduction of solids

Solids should preferably be introduced after the infant or child is established on a nutritionally complete feed. The restrictions imposed will depend on the underlying diagnosis. Often it is necessary to introduce food items singly to determine tolerance of different foods.

Inflammatory bowel disease

Crohn's disease

Crohn's disease (CrD) is caused by a chronic transmural inflammatory process that may affect any

Table 7.26 Example of a full strength modular feed using Complete Amino Acid Mix (per 100 mL).

	Energy						
	(kcal)	(kJ)	Protein (g)	CHO (g)	Fat (g)	Na^+ (mmol)	K^+ (mmol)
2.5 g Complete Amino Acid Mix	8	34	2	–	–	–	–
10 g Maxijul	38	160	–	9.5	–	–	–
6 mL Liquigen	27	113	–	–	3	0.1	–
1.4 mL NaCl (1 mmol/mL)	–	–	–	–	–	1.4	–
0.8 mL KCl (2 mmol/mL)	–	–	–	–	–	–	1.6
Final feed/100 mL	73	307	2	9.5	3.0	1.5	1.6

A vitamin and mineral supplement such as Paediatric Seravit is required to make a complete feed. This should be administered separately if the feed contains a fat emulsion and is being fed continually.

part of the GI tract from the mouth to the anus. It is an extremely heterogeneous disorder with great anatomical and histological diversity. The small intestine is involved in 90% of cases. The aggressive inflammatory process can cause fibrosis of the small bowel, stricture formation and ulceration leading to fistula formation. The aetiology of CrD is not yet fully understood but is now thought to be the result of an inappropriate immune response to the antigens of the normal bacterial flora in a genetically susceptible individual [47].

The presentation of CrD in children depends largely on the location and extent of the inflammation. In most cases it is insidious in onset with non-specific GI symptoms and growth failure often leading to an initially incorrect diagnosis [48]. It can also be associated with other inflammatory conditions affecting the joints, skin and eyes.

Over time, the disease causes nausea, anorexia and malabsorption. The mean energy intake of patients with active CrD has been found to be up to 420 kcal/day (1.75 MJ/day) lower than in age-matched controls [49]. The energy and protein deficit is reflected as weight loss (occurring in over 80% children) and a decreased height velocity [50]. Growth failure occurs in 15–40% children with CrD. In addition to a reduced oral intake, the pro-inflammatory cytokines that are increased in CrD have been shown to adversely affect growth [51]. Specific nutrient deficiencies such as calcium, magnesium, zinc, iron, folate, B_{12} and fat-soluble vitamins are common findings. During periods of active inflammation there is often enteric leakage of protein resulting in hypoalbuminaemia. Accompanying this is retarded bone mineralisation and development and delayed puberty [52,53].

Treatment

CrD is a chronic and as yet incurable disease and its management requires a combination of nutritional support, judicious use of drugs and appropriate surgery.

Enteral feeds as primary therapy

Nutrition as a treatment for CrD was identified in the 1970s. Since then many trials have been completed with the aim of establishing its efficacy as a primary therapy. These have compared enteral feeds with corticosteroids, a pharmacological treatment known to be effective in the treatment of CrD. They have also compared the effectiveness of different types of feed (elemental, hydrolysate and polymeric).

A systematic review published in 2001 aimed to evaluate the available evidence. The authors concluded that steroids were more effective than enteral nutrition in inducing remission in active CrD, although the latter was effective in inducing disease remission in a significant number of patients. There was no evidence to support an advantage of elemental formulas, the traditional feeds used in CrD, over polymeric (whole protein) feeds [54].

Confounding factors were that in adult studies, nasogastric tubes are not used in patients unable to complete the enteral feeds orally, which affected the results on an intention to treat basis. A CrD activity index has been used to assess clinical response to treatment. These indices are based on a combination of clinical and biochemical data and it is known that steroids favour the clinical index as they cause a feeling of wellbeing in patients [47]. A less rigorous meta-analysis of paediatric trials suggested that nutritional treatment and steroids were equally effective in children [55].

Although it is agreed that enteral feeds work for a significant number of patients, their mode of action is still not understood. Hypotheses include:

- Improvement in mucosal permeability leading to decreased antigen uptake and less stimulation of the gut-associated immune system
- Improved cell-mediated immunity
- Nutritional repletion in a malnourished patient
- Reduction in the intestinal synthesis of inflammatory mediators secondary to the low LCT content of some feeds used
- Altered bowel flora

Modulen IBD is a feed that has been designed specifically for patients with CrD. This has reported immunomodulatory effects brought about by the presence of transforming growth factor β (TGF-β), an anti-inflammatory cytokine present in casein. There are no published trials to date comparing this feed with other polymeric feeds.

The current evidence for enteral feeds as a treatment in active CrD is far from clear [50]. Most paediatric centres use enteral feeds as a primary therapy despite the increased cost compared with

steroids and the potential difficulty following the treatment prescribed. As children with CrD are often chronically malnourished, enteral feeds are important for nutritional repletion. Feeds are also preferable as a first line of treatment because of the deleterious effect of steroids on growth. There is currently only low quality evidence to confirm the benefits of feeds on growth in children [51].

Protocol for enteral feeding in Crohn's disease

Although there is convincing evidence that polymeric feeds are as effective a treatment as hydrolysate or elemental feeds, the author's current protocol uses two different feed types, the choice of which is decided by a history of atopy in either the patient or first degree relatives. For those patients with no history suggestive of possible food allergy, a polymeric, whole protein, casein based feed is used while in the atopic individuals a feed based on amino acids is used. Polymeric feeds have the advantage of being more palatable and are cheaper than the elemental alternatives.

Stopping food during the treatment period has been previously recommended without any supportive evidence. A recent randomised paediatric study compared children having 100% nutrition from enteral feeds (total enteral nutrition, TEN) with a second group who received 50% of their requirements from feeds and were allowed to eat normally (partial enteral nutrition, PEN). On analysis, nutritional parameters improved equally in both groups; however, blood indices of inflammation failed to improve in the PEN group, showing that significant amounts of food affects the anti-inflammatory response to enteral feeds [56]. The effect of allowing small amounts of food while having 100% nutritional requirements from feeds has never been examined.

For all feeds the following protocol can be applied:

- Feeds should be gradually introduced over 3–5 days depending on symptoms.
- The enteral feed should provide complete nutrition for a 4–8 week period. If the feed is well tolerated but the child has difficulty managing the volume, the concentration of powdered feeds may be increased to decrease the volume of enteral feed required.
- Clear fluids, boiled sweets and chewing gum are allowed orally by some centres to improve compliance.
- All solid food should be stopped for the duration of the treatment.

As patients with CrD are generally adolescents they find this particularly difficult and require a high degree of support and motivation to complete the treatment. Despite this, feeds are well tolerated by most patients and the full 6 weeks generally adhered to, with 72% of patients in one study reporting it as a preferred treatment or as acceptable as steroid therapy [57].

If the patient is sure that they will be able to manage orally, feeds can be introduced at home. If a nasogastric feeding regimen is required this is best started as an inpatient. Once the feed choice and prescribed volumes have been decided the aim is to give as much control to the patient as possible. Feeds should be tried orally with different flavourings and the volume required daily explained carefully. Patients are given the option of drinking the feed or using a nasogastric tube. If the former is decided on it is important that they understand that the prescribed volume needs to be completed every day as compliance can become an issue. If a tube is chosen patients are taught to pass this each night and remove it in the morning to cause minimum inconvenience to their daily routine. Some patients choose to drink the full volume even of hydrolysate feeds; others opt for a combination approach (a percentage orally and the remainder via the tube); some opt for solely nocturnal nasogastric feeds.

Nutritional requirements and monitoring

Most studies have failed to show increased basal energy requirements in patients with CrD unless the patient has a fever [52,58]. A recent study confirmed that measured resting energy expenditure (REE) in children with CrD fed with PN correlated well with the predicted REE using FAO/WHO/UNU equations and was not increased [59]. However, a prospective study showed that the median energy intake of enterally fed children with CrD was 117.5% of estimated average requirement (EAR) for energy for age [60].

The initial aim should be to provide 100–120% EAR for age for energy and the RNI for protein from the full feed, checking that all vitamins and minerals are present in amounts at least equivalent to the RNI [25]. It should be explained that childen are allowed to take a larger feed volume if they are still hungry. They should be weighed weekly and monitored by telephone contact. A follow-up

appointment should be arranged 2–3 weeks after discharge to ensure that the patient is responding to treatment and that weight gain is being achieved.

Introduction of foods and discontinuation of feeds
There is no agreement about the best methods of food introduction to patients completing a period of enteral feeds. In the UK, two main centres have published data with conflicting results. The East Anglian study found that a large number of patients were food intolerant, the most common foods cited as causing problems being corn, wheat, yeast, egg, potato, rye, tea and coffee [61]. This trial has been criticised as patients only completed 2 weeks of an elemental diet before foods were introduced which would not have been long enough to allow for full disease remission. This approach has been modified and a reduced allergen, low fat, low fibre diet devised to be introduced at the end of the 2–3 week period of enteral feeds with subsequent food reintroductions [62].

The group at Northwick Park Hospital introduced foods singly over 5-day periods after 4–8 weeks on complete enteral feeds. Food sensitivities could only be identified in 7% of the patients by double blind challenge. Most importantly, there was no significant difference in the duration of remission between patients who did or did not identify food sensitivities [63].

Beattie and Walker-Smith [64] concluded that neither study confirmed that intolerance to foodstuffs is seen in CrD and that no particular foods are known to exacerbate symptoms in a large group of patients.

Until there is further evidence it would appear prudent to reduce feed volume over a period of 2–4 weeks and gradually introduce a normal diet, ensuring that continued weight gain is maintained. Single food introductions do not seem worthwhile in the majority of patients and merely prolong the resumption of a normal diet. Patients found to be atopic and requiring a hydrolysate or amino acid based feed should be advised to exclude suspected food allergens, ensuring an adequate energy and calcium intake. Patients with a tight stricture in the ileum may require a low fibre diet to control symptoms until the stricture is surgically removed.

Long term outcome in Crohn's disease

Some patients require continued nutritional support either by nasogastric tube, gastrostomy or orally if appetite remains poor. It has also been reported that continued use of supplementary feeds in addition to a normal diet is associated with prolonged periods of disease remission and improved linear growth [57,65]. Studies have not been randomised and patient numbers are small. This is not current practice in UK centres at the time of writing.

A pilot study looking at quality of life (QOL) in a small group of children with apparently stable disease showed the impact of CrD. Difficulties in taking holidays, staying at friends' houses and inability to engage in school sports (because of lack of energy or presence of a stoma) were reported as well as frequently missing school. Future studies of treatment in children should attempt to assess the impact on the child's health-related QOL [66].

Ulcerative colitis

Like CrD, ulcerative colitis (UC) is a chronic, relapsing, inflammatory disease of the intestine which is confined to the colonic and rectal mucosa. It also has an unknown aetiology with evidence for an inherited predisposition to the disease alongside other, possibly environmental, factors. Tissue injury is most likely a result of non-specific activation of the immune system with some evidence that this has an auto-immune aetiology.

Drug therapy is used to induce and maintain disease remission. There is no evidence to support the use of enteral nutrition as a primary therapy in UC. The nutritional problems found in CrD are not as severe in UC because of the lack of involvement of the small intestine [53].

Nutritional support is needed if there is growth failure or weight loss and this can be given as a high energy diet and oral sip feeds.

Disorders of altered gut motility

Gastro-oesophageal reflux

Gastro-oesophageal reflux (GOR) refers to the inappropriate opening of the lower oesophageal sphincter (LOS) releasing gastric contents into the oesophagus. It is not a diagnosis and can be caused by differing pathologies. Approximately 50% of

infants regurgitate at least once a day and, in the majority of children, this can be considered as an uncomplicated self-limiting condition which spontaneously resolves by 12–15 months of age. This is because of the lengthening of the oesophagus and the development of the gastro-oesophageal sphincter.

More severe forms of this problem are found when an infant with regurgitation does not respond to simple treatment and develops gastro-oesophageal reflux disease. Acid induced lesions of the oesophagus and oesophagitis develop and are associated with other symptoms such as failure to thrive, haematemesis, respiratory symptoms, apnoea, irritability, feeding disorders and iron deficiency anaemia. GOR is a common finding in infants with neurological problems.

Treatment

Parental reassurance is very important and may preclude the need for any other measures. However, recurrent symptoms of inconsolable crying or irritability, feeding or sleeping difficulties, persistent regurgitation or vomiting may lead to unnecessary parental distress, recurrent medical consultations and may need further treatment.

Positioning

Postural treatment of infants has been demonstrated to help and a prone elevated position at 30° is the most successful in reducing GOR [67]. It is no longer possible to recommend this as several studies have shown an increased risk of sudden infant death syndrome (SIDS) in the prone sleeping position. It also requires the purchase of a special cot in which the baby has to be tied up to be kept in place, which is not always possible [68]. A systematic review concluded that raising the head of the cot was not beneficial to infants lying in the supine position [69]. A more practical approach is to avoid positions that exacerbate the situation. Young infants tend to slump when placed in a seat, which increases pressure on the stomach and makes the reflux worse. It is better to place them in a seat that reclines or to lie them down.

Feeding

The infant must not be overfed and should be offered an age-appropriate volume of milk. Small volume, frequent feeds may also be beneficial by reducing gastric distension (e.g. 150 mL formula/kg/day as 6–7 feeds). In practice frequent feeds may be difficult for parents to manage and reduced feed volumes may cause distress in a hungry baby.

The use of feed thickeners has been proven to reduce vomiting in infants, although pH monitoring shows that the gastro-oesophageal reflux index is not reduced [69,70]. Thickeners are well tolerated with very few side effects reported and should be used as a first line treatment in infants with regurgitation [68,69]. Caution has been urged by ESPGHAN that the indiscriminate use of thickening agents and pre-thickened formula should be avoided in healthy thriving infants who spit up feeds as the effects on nutrient bioavailability, metabolic and endocrine responses and frequency of allergic reactions to thickening agents are unknown [71].

Enfamil AR and SMA Staydown are nutritionally complete pre-thickened infant formulas based on cow's milk protein and are available on prescription (ACBS). Enfamil AR contains a high amylopectin, pre-gelatinised rice starch. It should be made with boiled water that has been cooled to room temperature to avoid lumps forming and the bottle then requires rolling between the hands to ensure proper mixing. SMA Staydown contains pre-cooked cornstarch and should be mixed with cold, previously boiled water. Both feeds thicken on contact with the acid pH of the stomach. The EC Scientific Committee for Food has accepted the addition of starch to a maximum of 2 g/100 mL in infant formula. Recommendations suggest that labelling should make it clear that 'AR' stands for 'Anti-Regurgitation' and not for 'Anti-Reflux' [72].

A variety of manufactured feed thickeners are on the market in the UK, based either on carob seed or modified maize starch (Table 7.27). Of the former, Instant Carobel has an advantage over Nestargel in that it thickens the feed without the need to be cooked. The complex carbohydrates in both products are non-absorbable and can lead, in a minority of infants, to the passage of frequent loose stools. Both products have the added flexibility of being mixed as a gel and fed from a spoon before breast feeds.

Where failure to thrive is a problem a starch based thickener can be used to provide extra energy. The lowest amount of thickener recommended should be added initially and the amount

Table 7.27 Feed thickeners for use in infancy available in the UK.

Product (Manufacturer)	Thickening agent	Suggested dilution (g/100 mL)	Added energy per 100 mL (kcal)	(kJ)	ACBS prescribable
Instant Carobel (Nutricia Clinical)	Carob seed	1–3	3–8	13–33	Y
Nestargel* (Nestlé)	Carob seed	0.5–1	Negligible		Y
Thick and Easy (Fresenius Kabi) Thixo-D (Sutherland) Vitaquick (Vitaflo)	Pre-cooked maize starch	1–3	4–12	17–50	Y†

ACBS, Advisory Committee on Borderline Substances.
* Product requires cooking before use.
† Only prescribable for <1 year in cases of failure to thrive.

gradually increased to the maximum level if there is no resolution of symptoms. Feeding through a teat with a slightly larger hole, or a variable flow teat, is recommended. Ordinary cornflour can also be used as a thickening agent for infant feeds but has the inconvenience of requiring cooking. This should be done in approximately half of the volume of water required for the final feed recipe and cooled before the formula powder is added. Such feeds generally require sieving before use.

Comfort First Infant Milk and Follow-on Milk are thickened infant and follow-on formulas made from partially hydrolysed whey protein that contain prebiotic oligosaccharides. They are designed for bottle fed babies with minor feeding problems.

Food allergy

In more complicated GOR that fails to respond to simple treatment, a therapeutic change of formula should be considered as it has been demonstrated that GOR can be secondary to food allergy. Two studies have demonstrated that 30–40% of infants with GOR resistant to treatment have cow's milk allergy, with symptoms significantly improving on a cow's milk protein free diet [73,74]. In food sensitive patients cow's milk has been shown to cause gastric dysrhythmia and delayed gastric emptying which may exacerbate GOR and induce reflex vomiting [75]. The use of protein hydrolysate feeds in these infants for a trial period should be considered as a treatment option (Table 7.7).

Medical treatment

Medications that can be used to treat GOR range from antacids to H_2 antagonists, such as ranitidine which reduces gastric acid secretion; proton pump inhibitors such as omeprazole; and prokinetic agents, such as domperidone, which elevates the LOS pressure and increases gastric emptying. A combination of these is often given to control symptoms.

In extreme cases that do not respond to the above treatments, surgery may be needed to correct the problem. A fundoplication which wraps the fundus of the stomach around the LOS creates an artificial valve and prevents GOR (see p. 129). A gastrostomy is usually inserted for venting gas from the stomach and, occasionally, for feeding purposes. There is considerable morbidity associated with this operation.

Feeding problems in GOR

Feeding difficulties are common in this disorder and are characterised by oral motor dysfunction, episodes of dysphagia and negative feeding experiences by both mother and baby. Infants with GOR are significantly more demanding and difficult to feed and have been found to ingest significantly less energy than matched infants without GOR [76]. These problems often persist after medical or surgical treatment with the continuing aversive behaviour being caused by associating pain with previous feeding experiences.

Where there are severe feeding problems it may be necessary to instigate feeding via a nasogastric tube or gastrostomy to ensure an adequate nutritional intake. Wherever possible an oral intake, however small, should be maintained to minimise

later feeding problems. The child's feed should be administered as oral or bolus day feeds with continuous feeds overnight at a slow rate to avoid feed aspiration. The feed volume may need to be reduced below that recommended for age to ensure tolerance, with feeds fortified in the usual way to ensure adequate nutrition for catch-up growth. If using a fine bore nasogastric tube to administer bolus feeds, thickening agents should be kept to the minimum concentration recommended to prevent the tube blocking and an inappropriate length of time being taken to administer the feed. There is no evidence that reduced fat feeds promote gastric emptying and reduce GOR in these infants [72].

The requirement for tube feeding can continue for prolonged periods of time, as long as 36 months in one study [77]. Parents of infants with feeding problems secondary to GOR need a great deal of support. Optimal management should employ a multidisciplinary feeding disorder team including a psychologist with experience of children with these problems, a paediatrician, a dietitian and a speech and language therapist.

Constipation

Constipation is a symptom rather than a disease and can be caused by anatomical, physiological or histopathological abnormalities. Idiopathic constipation is not related to any of these and is thought to be most often caused by the intentional or subconscious withholding of stool after a precipitating acute event. Constipation has been found to account for 3% of visits to general paediatric outpatient clinics and 10–25% of visits to a paediatric gastroenterologist, so is a sizeable problem.

Average stool frequency has been estimated to be four stools per day in the first week of life, two per day at 1 year of age, decreasing to the adult pattern of between three per day and three per week by the age of 4 years. Within these patterns there is a great variation. The Paris Consensus on Childhood Constipation Terminology (PACCT) Group [78] defined chronic constipation as the occurrence of two or more of the following characteristics during the last 8 weeks:

- Less than three bowel movements per week
- More than one episode of faecal incontinence per week
- Large stools in the rectum or palpable on abdominal examination
- Passing of stools so large they obstruct the toilet
- Retentive posturing and withholding behaviour
- Painful defaecation

In idiopathic constipation prolonged stretching of the anal walls associated with chronic faecal retention leads to an atonic and desensitised rectum. This perpetuates the problem as large volumes of faeces must be present to initiate the call to pass a stool. Faecal incontinence (previously described as encopresis or soiling) is mostly as a result of chronic faecal retention and rarely occurs before the age of 3 years.

Treatment

Acute simple constipation is usually treated with a high fibre diet, sufficient fluid intake, filling out a stool frequency diary and toilet training. Treatment of chronic constipation is based on four phases:

- Education of the family to explain the pathogenesis of constipation
- Disimpaction using oral or rectal medication
- Prevention of re-accumulation of faeces using dietary interventions, behavioural modifications and laxatives (a mixture of osmotic laxatives such as lactulose, stimulants such as senna and mineral oils can be used)
- Follow-up [79]

Dietary fibre can be classified into water soluble and insoluble forms. The former includes pectins, fructo-oligosaccharides (FOS), gums and mucilages that are fermented by colonic bacteria to produce short chain fatty acids. This has been shown to increase stool water content and volume. Insoluble fibre mainly acts as a bulking agent in the stool by trapping water in the intestinal tract and acting like a sponge. Both soften and enlarge the stool and reduce GI transit times.

Surveys have shown that constipated children often eat considerably less fibre than their non-constipated counterparts. Even when advised to increase their fibre intake by a physician the fibre intake was only half of the amount of the control population. It appears that families can only make the necessary changes with specific dietary counselling [80]. Children with chronic constipation have also been shown to have lower energy intakes

and a higher incidence of anorexia. It is difficult to know if this existed previously and predisposed to the condition or whether it is caused by early satiety secondary to constipation [81].

There are currently no guidelines in the UK for appropriate fibre intakes in children. In the USA recommendations are for children older than 2 years to consume daily a minimum number of grams of dietary fibre equal to their age in years plus 5 g/day (e.g. a 4-year-old should have a minimum of 4 + 5 = 9 g fibre/day) [82]. In infancy and childhood it is important to ensure that adequate fluids are taken. As a guide children should have 6–8 drinks a day preferably as water or juice and including any milk. For children who continue to drink insufficient amounts foods with a high fluid intake should be encouraged such as ice lollies, jelly and sauces. Fruit, vegetables and salad have a high fluid content as well as being desirable because of their fibre content.

In babies, the addition of carbohydrate to feeds can induce an osmotic softening of the stool but is not to be encouraged as a general public health message. Once solids are introduced these should include fruit and vegetables, with wholegrain cereals being introduced after the age of 6 months. Bran should not be used in infancy and with caution in older children.

In the 1999 American evidence based guidelines, no randomised controlled trial was found that showed an effect on stools in constipated children of any of the above dietary measures [79]. The fact that constipation is uncommon in societies that consume a high fibre diet has been used to justify this treatment. More recently, a double blind randomised control trial (DBRCT) studying the effects of infant cereal supplemented with FOS in normal infants showed that this resulted in more frequent and softer stools [83]. Another DBRCT using glucomannan as a water-soluble fibre supplement in the diet of children aged 4 or older with chronic constipation showed a beneficial outcome [84]. There are currently no confirmed positive effects of the use of probiotics in constipation.

Food allergy

In a select group of children with constipation who fail to respond to conventional treatment, cow's milk protein free diets have been shown to be beneficial [85]. Motility studies in these patients have indicated that the delay in faecal passage is a consequence of stool retention in the rectum and not of a generalised motility disorder [86]. It has therefore been proposed that all children with chronic constipation that fails to respond to normal treatment as outlined above should be considered for a trial of a cow's milk free diet (Table 7.6), especially if they are atopic [87]. A recent study showed that, of 52 patients with chronic constipation, 58% had an eosinophilic proctitis caused by an underlying food allergy. This was confirmed by double blind food challenges. The majority were intolerant of cow's milk protein; however, six patients had multiple food intolerances identified by the use of a few foods diet [88].

Gut motility disorders

Integration of the digestive, absorptive and motor functions of the gut is required for the assimilation of nutrients. In the mature gut, motor functions are organised into particular patterns of contractile activity that have several control mechanisms.

After swallowing, a bolus of fluid or food is propelled down the oesophagus by peristalsis; this action differs from the motility of the rest of the intestine in that it can be induced voluntarily. The LOS relaxes to allow food or fluid to pass into the stomach which acts as a reservoir and also initiates digestion. It has a contractile action that grinds food to 1–2 mm particle size. Gastric emptying can be modulated by feed components via hormonal secretion. LCTs have been found to inhibit gastric emptying. Different dietary proteins also have an effect with whey hydrolysates emptying more rapidly than whole protein feeds [89].

In the small intestine, motor activity is effected by smooth muscle contraction which is controlled by myogenic, neural and chemical factors. In the fasting state the gut has a contractile activity (the migrating motor complex) that keeps the luminal bacteria in the colon. Abnormalities of this phasic activity can result in bacterial overgrowth of the small intestine and malabsorption. Post-prandial activity is initiated by hormones and food eaten to produce peristalsis in the gut, relaxation of the muscle coats below and contraction above the bolus of food through the intestine. Disturbances in this co-ordinated system can occur at all levels.

Toddler diarrhoea

Toddler diarrhoea, also known as chronic non-specific diarrhoea, is the most frequent cause of chronic diarrhoea in children between the ages of 1 and 5 years of age. Symptoms include frequent watery stools containing undigested foodstuffs in a child who is otherwise well and thriving. Despite the children generally presenting in a good nutritional state, parental anxiety is high. The diarrhoea ceases spontaneously, generally between 2 and 4 years of age.

Proposed mechanisms

A primary problem has still not been identified. Children with this disorder are known to have a rapid gut transit time and intestinal motility is generally thought to be abnormal, although it is unsure whether this is caused by a reduced colonic transit time or a disturbance of small intestinal motility.

Carbohydrate malabsorption, particularly of fructose, has been extensively investigated in this disorder. Fructose is known to be slowly absorbed in the small intestine and is often present in large amounts in fruit juice. In recent years, the diets of children in this age group have undergone changes with an increase in the amount of fruit squash and fruit juices and a decrease in water taken as drinks [90]. As apple juice particularly has been implicated as causing toddler diarrhoea, studies have been completed using hydrogen breath tests to measure carbohydrate malabsorption. What now seems to be evident is that non-absorbable monosaccharides and oligosaccharides such as galacturonic acid are produced by enzymatic treatment of the fruit pulp in clear fruit juices, including apple, grape and bilberry juices. It is thought that these may cause problems in sensitive individuals, rather than fructose [91].

Treatment

All sources agree that parental reassurance is of primary importance. The role of diet in this disorder is controversial [43,92]. Advice is needed to correct any dietary idiosyncracies. Excessive fluid intake, particularly of fruit juices and squash, should be discouraged. Fibre intake has frequently been reduced by parents in an attempt to normalise stools, therefore increasing this to normal levels should be recommended. Fat intake may also have been reduced, either because of the excessive consumption of high carbohydrate fruit drinks or for health reasons, and should be increased to 35–40% of total dietary energy. Often parents have tried excluding foods from the child's diet, mistakenly believing the problems to be brought about by food intolerance. Once the diagnosis is established these foods should be reintroduced.

Chronic idiopathic pseudo-obstruction disorder

This term embraces a heterogeneous group of disorders that cause severe intestinal dysmotility with recurrent symptoms of intestinal obstruction in the absence of mechanical occlusion. Gut transit time is generally in excess of 96 hours. The cause is usually an enteric myopathy or neuropathy that can also affect the urinary tract [93]. It is an extremely rare disorder with a high morbidity and mortality.

Nutritional support is vital for these children. In one series of 44 patients, 72% required parenteral nutrition for a relatively long period of time, seven children dying of PN related complications with a further 10 remaining dependent on long term home PN [94].

Full enteral nutrition is possible to achieve in some patients but needs to be started slowly, with a gradual decrease in PN volume as the enteral nutrition is increased. Particular attention needs to be paid to fluid and electrolyte requirements. Many of the children have an ileostomy to decompress the gut. The loss of sodium rich effluent through the stoma generally results in high sodium requirements (up to 10 mmol/kg/day). Enteral feed can be pooled in the intestine for a prolonged period of time before passing through the stoma, resulting in a lack of appreciation of the relatively high fluid requirements of these children. In certain children (especially those with a migrating motor complex), jejunal feeding may be successful if a trial of gastric feeds have failed [95].

Treatment

The following suggestions for the nutritional management of these patients have proved beneficial:

- Liquids are easier for the dysmotile gut to process than highly textured foods. Aim to give full requirements from the feed or PN, or a combination of the two, to minimise intake of solids.
- Enteral feeds are more likely to be tolerated as a continuous infusion than as bolus feeds.

- Whey hydrolysates have been found to empty more rapidly from the stomach and form the mainstay of treatment [89].
- Care should be taken to ensure that enteral feeds are made as cleanly as possible to prevent the introduction of organisms into the gut, which could contribute to bacterial overgrowth. In older children the use of sterile feeds is preferable.
- Fluid and sodium requirements should be accurately assessed and supplements given as needed.
- Where solids are taken these should be low in fibre so as not to cause obstruction. Semi-solid or bite-dissolvable consistencies such as purées, mashed potato and puffed rice cereal will be more easily digested.

In these children weight measurements are not always accurate because of distended loops of gut pooling large quantities of fluid. They should be used in conjunction with other anthropometric measurements such as mid-arm circumference or skinfold thicknesses to assess nutritional state.

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Resource

Dietitians working in paediatric gastroenterology in the UK are encouraged to join the Associate Members group of the British Society of Paediatric Gastroenterology, Hepatology and Nutrition (BSPGHAN) www.bspghan.org.uk.

Useful addresses

Coeliac UK
Suites A–D, Octagon Court, High Wycombe, Bucks, HP11 2HS
Tel 01494 437278
www.coeliac.co.uk

CICRA (Crohn's in Childhood Research Association)
Parkgate House, 356 West Barnes Lane, Motspur Park, Surrey, KT3 6NB
Tel 020 8949 6209
www.cicra.org

Gut Motility Disorders Network
Westcott Farm, Oakford, Tiverton, EX16 9EZ
Tel: 01398 351173

Half PINNT (For children on intravenous and nasogastric feeding)
PO Box 3126, Christchurch, Dorset, BH23 2XS
www.pinnt.co.uk

NACC (National Association for Colitis and Crohn's Disease)
4 Beaumont House, Sutton Road, St Albans, Herts, ALI 5HH
Tel 0845 130 2233
www.nacc.org.uk