

Progress report

Elemental diets

The term 'elemental diet' is applied to a food which contains an elemental protein source, in the form of amino acids, with other easily digestible nutrients, minerals, and vitamins added; fat is present in very small quantities. Such a diet may also be described as 'chemically defined', the elemental components being pure chemical entities.

Origins and Developments

The possibility of developing diets of this type has been considered for many years.^{1,2} Little progress was made, however, until Rose and his associates were able to demonstrate that experimental animals could grow satisfactorily on mixtures of relatively simple but well defined nutrients, and that human beings could be maintained in positive nitrogen balance.^{3,4} Based on knowledge acquired from these and other early investigations,⁵⁻⁸ a series of quantitative nutritional studies was performed using water-soluble, chemically defined diets.⁹⁻¹⁸ In these animal studies, nitrogen was supplied exclusively in the form of optically pure l-amino acids, and the diets were administered as single aqueous solutions which were nutritionally complete. These diets were shown to support normal growth, life span, and reproduction in laboratory animals. Initial clinical studies in man demonstrated that patients on minimal-residue elemental diets given over many weeks were maintained in good health with no untoward physiological or psychological responses and exhibited no evidence of complications.¹⁹⁻²³

A further impetus in the development of elemental diets and the investigation of their properties came from the American aerospace programme, although some 'space diets' may be mixtures of natural foods, and thus not truly 'elemental'.

Properties of Elemental Diets

On the basis of these initial studies, the principal characteristics of minimal-residue, elemental diets have now been defined, and many of these may be of value in the management of human disease states.^{22,24,25}

HIGH NUTRITIONAL EFFICACY

Small amounts of liquid elemental diets will provide the requirements of essential and non-essential nitrogen, mineral salts, vitamins, and fats, together with up to 3000 calories daily and about a quarter of the water requirements for a period of a month. The nutritional value of elemental diets is thus high.

UNIFORM BUT FLEXIBLE COMPOSITION

The composition of chemically defined diets is uniform and reproducible.

These diets also provide a degree of flexibility in relation to nutrients, thus making it possible to tailor the composition of the diet to meet specific nutritional requirements.

LOW FAECAL BULK

Diets of this type contain no indigestible bulk or fibrous material, and their administration leads to a considerable reduction in gastrointestinal bulk. The average stool weight is greatly reduced and frequency of elimination decreased. The stools contain less solid matter, are watery, and frequently dark green or black.^{21,22}

MINIMAL DIGESTION REQUIRED

Elemental diets are almost totally absorbed in the upper small intestine, leaving only the endogenous residue to enter the large bowel.^{23,26} They provide dietary components in a readily assimilable form, without the need for digestion, thus bypassing the requirements of pancreatic and biliary secretion. There is evidence both in animals and in man that pancreatic secretions are stimulated to a lesser extent when elemental diets are administered.^{27,28,29-33} In addition, as they contain essentially no fat, they do not require micelle formation.

ALTERATION OF GASTROINTESTINAL BACTERIAL FLORA

Glucose-based elemental diets have been reported to cause a reduction in the total microbial population in faeces, and in some subjects on such a diet no microorganisms were detectable after 12 days.^{34,35} However, subsequent studies have shown a reduction in enterococci and an increase in the enterobacteria was noted in the faeces.^{36,37} The average counts of total anaerobes, aerobes, and coliforms in the stool did not vary significantly. Crowther and his colleagues³⁸ found an alteration in the degree of degradation of faecal neutral steroids, which might indicate some alteration in the anaerobic flora. The daily faecal bile acid excretion rate was considerably reduced during the period that the elemental diet was administered. A reduction in the faecal bile acid output has also been found in postvagotomy diarrhoea treated with an elemental diet.³⁹ Although changes in faecal bacteria do not necessarily reflect what is happening to enteric bacteria,⁴⁰ it appears that liquid elemental diets can alter the bacterial flora in the gastrointestinal tract to some extent, resulting particularly in a decrease in the number of enterococci.

Further information is required on the effect of elemental diets on the bacterial flora of the gastrointestinal tract, in view of the possible therapeutic value of these diets in altering the flora in various disease processes.

EFFECT ON BLOOD PRESSURE AND SERUM LIPID LEVELS

A fall in both the systolic and diastolic blood pressure levels has been noted in patients on elemental diets.^{21,22} The blood pressure levels of these subjects, all of whom were normotensive, returned to baseline within a few days of restarting a normal diet.

The use of chemically defined diets has also been associated with a decrease in serum cholesterol levels,^{21,22,41-44} although the nature of the carbohydrate base of the diet may alter this effect.

GASTRIC SECRETION AND EMPTYING

A significant reduction in gastric acid secretion in man has been shown to occur with elemental diets.^{27,28,45} This is considered to be due partly to a reduction in the cephalic phase of gastric secretion, and possibly also partly by a reduction in the local stimulatory effects of the predigested diet. Bolus feeding of an elemental diet has also been shown to delay gastric emptying significantly in man.³⁸

HYPOALLERGENICITY

Elemental diets may be capable of providing protein-free nutrition to individuals liable to food allergy due to permeability of the gastrointestinal tract to unaltered protein.

COMPLETE WATER SOLUBILITY

This characteristic allows the administration of elemental diets in liquid form where solid foods cannot be used. They may thus be used in tube feeding, for the nutritional support of infants and the elderly, and in patients who are unable to masticate because of dental or oral surgery.

MAINTENANCE OF STABLE CONDITIONS SUITABLE FOR METABOLIC STUDIES

The uniform and reproducible nature of chemically defined diets allows accurate measurements of the intake of all nutritional compounds. They are thus suitable for establishing a stable, steady state suitable for metabolic studies, particularly in view of the fact that many compounds normally found in the urine have primarily a dietary origin. An elemental diet causes a decrease in urinary electrolytes, urea, and uric acid within a few days of starting the diet,⁴⁴ and urinary excretion of minerals, including magnesium, calcium, and phosphorus is also increased.⁴⁶

GOOD STORAGE CAPACITY

Elemental diets can be stored for up to 12 months in the dry state without appreciable deterioration when kept below 60°F. When made into solution, they make good culture media, and should not be kept for more than 24 hours, and then only if refrigerated.

Indications for the Use of Elemental Diets

There is a wide range of indications for the use of elemental diets, being based on the characteristic properties of the diets. Many of the potential uses are still under investigation, and much information is still required as to the value of this form of therapy in the management of many disease processes.

POSTOPERATIVE MANAGEMENT AND PREOPERATIVE PREPARATION

Many patients require special nutritional support following surgery, and elemental diets may assist in the management of such patients.⁴⁷ The property of minimal residues of elemental diets may also be of value in colonic and rectal surgery where a reduction in the faecal output may assist healing,⁴⁸⁻⁵⁰ and in neonatal and paediatric surgery where it may be difficult to maintain

adequate nutrition following operation.⁵¹⁻⁵⁴ They may also be of value in the nutritional care of patients who have undergone head and neck surgery.⁵⁵

Elemental diets may have an important part to play in the preparation of the colon for operation. The bacterial flora of the colon before surgery may not be altered by elemental diets, but they may be of value in the mechanical preparation of the colon while maintaining the patient in an adequate nutritional state.^{48,51,56-59}

THE MANAGEMENT OF GASTROINTESTINAL FISTULAE

The mortality of chronic gastrointestinal fistulae is generally high, ranging from 40 to over 70%.⁶⁰⁻⁶² Bury, Stevens, and Randall (1969)⁶³ were able to reduce the mortality rate in 13 patients to 15.4% using elemental diets. A positive nitrogen, potassium, and magnesium balance was achieved in a significant number of patients, and while on the diet the patients' weights were maintained and serum protein levels increased; over half of the fistulae closed spontaneously.

The use of conventional food requiring digestion often exacerbates fistula drainage, and the patient may be unable to ingest or absorb the amount of calories and nutrients required for positive caloric and nitrogen balance. The use of chemically defined, residue-free elemental diets for human nutrition in the treatment of catabolic states was reported by Stevens and Randall (1969),⁶⁴ and the application to the management of chronic gastrointestinal fistulae has so far been one of the most successful uses of this form of therapy. A number of other reports of the successful application of elemental diets in the management of gastrointestinal, rectovaginal, and gastrointestinal cutaneous fistulae have now appeared.^{47,59,65-72}

MALDIGESTION AND MALABSORPTION STATES

The nature of elemental diets, requiring little or no digestion in the upper alimentary tract and no micelle formation, offers a potential advantage in the management of patients with maldigestion and malabsorption states. Several reports have now appeared describing the use of elemental diets in the treatment of chronic pancreatic insufficiency.^{30,59,73} In one report, seven of eight patients with marked steatorrhoea and weight loss who did not improve with standard pancreatic replacement therapy responded well to the use of an elemental diet administered either as the sole source of nutrition or as a supplement.⁵⁹ These patients may have diabetes mellitus and the additional glucose load may require an adjustment of insulin dosage.

The use of elemental diets may be particularly valuable in the management of patients with the short bowel syndrome.^{51,52,74,75} Patients in whom up to 75% of the small intestine has been resected may remain in reasonably good health^{76,77} but those with more extensive resections may not survive for long periods.⁷⁸ During the period of adaptation which follows massive small intestinal resection, nutritional support may be obtained by using an elemental diet.⁷⁹ Adaptation in such patients may be related to luminal nutrition which may encourage intestinal mucosal growth.⁸⁰ The use of an elemental diet following an initial period of intravenous feeding would appear to be the treatment of choice in such patients at present.

It is possible that elemental diets may be of value in the management of malabsorption and maldigestion states which are unresponsive to conventional therapy. Thus, some patients with coeliac disease who do not respond

to a gluten-free diet and patients with cystic fibrosis may benefit from elemental diet therapy.

INFLAMMATORY BOWEL DISEASE AND OTHER DIARRHOEAL STATES
In Crohn's disease when either excessive diarrhoea or obstructive symptoms are predominant, the low-residue nature of elemental diets may improve the symptomatology. Chronic malnutrition and malabsorption, local chronic infection, and chronic fistulae in Crohn's disease may also respond to elemental diet therapy.^{51,64,75,81-85} To date, there has been no controlled assessment of the place of elemental diets in the management of Crohn's disease, but their main value appears to be in the management of those patients with severe diarrhoea, malabsorption, fistulae, and perianal ulceration.^{86,87}

Little specific information is available regarding the use of elemental diets in the management of ulcerative colitis. It is possible, however, that in severe exacerbations of the disease elemental diet therapy with its quality of low residue may be of some value.^{75,81,84,88,89} Controlled observations of the effect of elemental diets in acute exacerbations of ulcerative colitis are required.

Elemental diet therapy has also been suggested in the management of patients with the irritable colon syndrome²⁵ and diverticular disease⁹⁰. It may also be of some value in diarrhoeal states induced by excessive faecal excretion of bile acids, such as postileal resection diarrhoea and postvagotomy diarrhoea,⁹¹ as a reduction in faecal bile acid excretion has been found with elemental diets.^{38,39}

PHENYLKETONURIA AND MENTAL DEFICIENCY

Long-term treatment of phenylketonuric children with a low phenylalanine-chemically-defined diet has been shown to be of considerable benefit.⁹²⁻⁹⁴ The children gained weight, and had a decrease in size and frequency of bowel movements, thus leading to more efficient and satisfactory institutional care. The incidence of abdominal discomfort and flatulence also diminished.

Last noted a similar beneficial effect in 11 patients with severe mental deficiency.⁹⁵

MANAGEMENT OF PATIENTS SUFFERING FROM CANCER

Elemental diets may have an important part to play in the management of severely debilitated patients suffering from cancer. In addition to promoting a positive metabolic balance, there is evidence from animal and human studies that chemically defined diets may protect the patient from weight loss and rectal lesions during chemotherapy.^{96,97} The cancer patient may also obtain some benefit during radiotherapy.⁹⁸ In many patients with cancer there are secondary atrophic changes in the small intestinal mucosa leading to a degree of malabsorption,⁹⁹ and elemental diet therapy may improve their protein-calorie malnutrition and in some cases the secondary malabsorption.

ACCELERATED METABOLIC STATES

Elemental diets are of value in the management of accelerated metabolic states, especially when the patient cannot eat, as after severe trauma¹⁰⁰ or operations to the head and neck.⁵⁵ Similarly, patients suffering from severe

burns may benefit from elemental diets which may be given in addition to a regular diet. Nitrogen balance in the severely burned patient will improve, and the reduction in stool bulk may limit a possible source of infection.^{101,102}

HEPATIC FAILURE

Although there is conflicting evidence concerning the effect of elemental diets on colonic and faecal flora patterns, ammonia-producing organisms in the colon may be reduced by the use of chemically defined diets.²⁵ The only published report refers to four patients with hepatic cirrhosis and hyperammonaemia who were treated exclusively with an elemental diet; a decrease in the high blood ammonia level was noted.¹⁰³ Quantitative and qualitative alterations in the intestinal flora may be of benefit in the treatment of hepatic encephalopathy, although the high amino acid content of the diet must be regarded as a potential hazard.

PREPARATION FOR DIAGNOSTIC PROCEDURES

Elemental diets may be of value in the preparation of the colon for diagnostic procedures. Thus, a few days' treatment may empty the colon, and allow a greater likelihood of success in diagnostic procedures such as colonic radiology^{48,59} and colonoscopy.^{104,105}

OTHER POSSIBLE USES OF ELEMENTAL DIETS

Chemically defined diets have been used in the management of frequent intercurrent infections associated with impaired immunological function.¹⁰⁶ In the patient described, there was evidence of catabolism in excess of tissue repair and some compensation was achieved by the use of an elemental diet.

Preliminary studies in animals have suggested that elemental diets may protect the intestine against the deleterious effects of shock,^{107,108} and so their potential role in the management of hypercholesterolaemia requires to be elucidated.⁴²⁻⁴⁴

Disadvantages and Potential Dangers of Elemental Diets

Elemental diet therapy presents a number of hazards and disadvantages, which must be recognized.

UNPALATABILITY

One of the disadvantages of this form of treatment is the relative unpalatability of the diet. A variety of flavourings are available which may improve the taste and make it more acceptable to patients. In some cases, however, intragastric administration may be necessary.

GASTROINTESTINAL SIDE EFFECTS

Nausea may occur if an elemental diet is ingested too rapidly. The high sugar content may produce osmotic effects which can result in diarrhoea.²⁵ Gastric retention can also be a problem, due to hypertonicity,⁴⁵ especially if the diet is administered by means of an intragastric tube.

DISTURBANCE OF WATER BALANCE

A positive effect of a high carbohydrate energy substrate on water balance has been reported. This is seen with the sudden change from a high fat to a high carbohydrate energy substrate.¹⁰⁹ Overhydration may also occur,

particularly if intravenous feeding is not decreased with the increase in alimentary feeding.⁶³

Symptoms of dumping may be seen, particularly in patients with a weak pyloric mechanism.^{25,26}

The nature of the diets introduces the danger of hypertonic dehydration, hyperosmolar non-ketotic coma, and osmotic diuresis.^{24,50,63,110} This is particularly likely with concentrations over 25% w/v when additional water is mandatory to prevent these complications. Patients will usually regulate their own water balance if allowed to drink water freely. These complications are particularly liable to occur in infants and it may be avoided if the diet is started slowly at isotonic concentrations and increased over four or five days to a level of about 10 to 12% w/v.

HYPOPROTHROMBINAEMIA

Hypoprothrombinaemia with subsequent haemorrhage may have been a danger of long-term therapy with the elemental diets originally available.⁶³ They contained no vitamin K, and may have caused depression of bacterial synthesis of vitamin K due to alteration of bacterial flora in the gastrointestinal tract.²⁵ With the commercially available diets today hypoprothrombinaemia does not appear to be a problem.

SKIN RASHES

A variety of skin rashes have been reported in some patients on elemental diet therapy but these may clear while the diet is continued.^{63,84}

HYPERGLYCAEMIA

This can be a problem in patients with diabetes mellitus or in those on steroid therapy. If elemental diets are used in chronic pancreatic insufficiency in which diabetes mellitus is common, the additional glucose load may necessitate adjusting the insulin dosage. If this is not recognized a hyperosmolar syndrome may result.⁵⁹

PANCREATIC ACINAR ATROPHY

This condition has been reported in rats and mice on elemental diet therapy.^{32,111,112} The incidence in man, however, does not appear to differ significantly from malnourished patients not receiving an elemental diet.²⁵

ASPIRATION

Aspiration of the diet is a hazard with intragastric feeding, particularly in elderly and debilitated patients.⁶³

Composition and Administration of the Diet

The standard elemental diet available at present in Britain consists of chemically identified individual amino acids reconstituted into mixtures which provide defined amounts of essential amino acids together with non-essential amino acids.¹ Carbohydrate is present in the form of glucose and glucose oligosaccharides, and supplies approximately 90% of the energy contribution to the diet. The diet contains less than 1% fat in the form of highly purified safflower oil (80% as triglyceride of linoleic acid). Electrolytes,

¹Vivonex: Eaton Laboratories, 125 High Holborn, London, WC1V 6QX.

water-soluble, and fat-soluble vitamins are added at minimal daily requirement levels for normal man. The diet may also be relatively deficient in zinc and magnesium. These elements may be low in a number of the diseases for which elemental diets are of value,¹¹³ and supplements may be required.

The methods of administration depend upon the indication for the use of the diet. It may be used as a supplement to a normal diet or as a complete dietary regime in itself. It may be administered orally or via intragastric or intrajejunal tubes.

When given orally, the liquid diet should be ingested in small amounts because of the high osmolality. Additional water should be given freely. Tube feeding may be accomplished by means of an intragastric feeding tube with a variable speed pump suitable for controlling volume and rate of flow. The initial concentration in adults should be 12.5-15% w/v with an administration rate initially of 40 to 60 ml/hour. The concentration can be increased to 25% w/v in 24 hours if the patient has no nausea, vomiting, or significant gastric retention. The volume is then progressively increased until the desired calorie and protein intake is achieved.²⁴

In patients on elemental diet therapy, blood and urine glucose levels should be checked frequently. In seriously ill patients plasma electrolyte concentration and pH should be checked daily during the initial period of therapy. Electrolyte and water supplements are administered as required intravenously or via the intragastric tube. In some instances elemental diet therapy may follow on from initial parenteral nutrition.

Elemental Diets and Parenteral Nutrition

Intravenously administered mixtures of hydrolysed protein in glucose developed over recent years have offered some progress in the management of a number of complex metabolic and surgical problems.¹¹⁴⁻¹¹⁶ Although many patients will continue to require parenteral nutrition, the advent of elemental diets has offered an alternative form of therapy. Elemental diet therapy may follow on an initial period of parenteral nutrition in some patients but in others it may replace intravenous nutrition altogether.

Elemental diets have an advantage over intravenous nutrition in that they are easier to administer and allow greater flexibility in the use of trace elements. Parenteral nutrition carries the risk of infection caused by intravenous catheters,^{63,117} and may be followed by metabolic acidosis¹¹⁸ and hypophosphataemia.^{119,120} As previously mentioned, the use of luminal nutrition may encourage intestinal mucosal growth.⁸⁰ The cost of elemental diet therapy is also somewhat less than that of intravenous feeding.¹²¹

Conclusions

The effectiveness of chemically formulated minimal-residue diets in maintaining adequate human nutrition has now been well documented, and their properties have been largely worked out. Their compact and predigested nature, together with their low intestinal bulk-producing qualities, offer special advantages in various disease states. Thus, in a number of post-operative conditions—the management of fistulae, preoperative bowel preparation, maldigestion, and malabsorption states—elemental diets have been shown to be of particular advantage. Their use in other conditions such

as ulcerative colitis, Crohn's disease, hepatic insufficiency, and other conditions requires further study, but these diets may find a place in treating individual patients with such conditions. The identification of such patients requires further study.

The disadvantages of their use have also been well defined. Although much is known of this, more information is required about the possible consequences of long-term feeding of such diets.

Elemental diets are a stimulating medical development which, although requiring further assessment, are likely to be of therapeutic value to a large number of patients.

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