Transition from Parenteral to Enteral Nutrition

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Abstract

Children are unique as their food intake must provide sufficient nutrients not only for the maintenance of body tissues but also for growth. Improvements in techniques for nutritional support has resulted in very long term parenteral nutrition being available for those with chronic intestinal failure in addition to those who require short term parenteral feeding either following surgery or whilst treatment for an underlying enteric disease becomes effective. Parenteral nutrition is required whenever insufficient nutrients cannot be provided enterally to prevent or correct malnutrition or to sustain appropriate growth. Somatic growth is fastest in infancy and puberty but other organs such as the brain may only grow and differentiate at one particular time. When a period of more liberal feeding intervenes catch-up of growth and function occurs. In adolescence the risk is of not achieving growth potential. Timing and methods of weaning from parenteral to normal nutrition remain controversial. In infants and children it is essential to consider carefully whether gastrointestinal function is sufficient for enteral nutrition to adequately support them. Thus the time when the infant and child can be weaned from parenteral nutrition will depend both on the activity of the underlying disease and the age and size of the infant or child.

Introduction

Children are unique as optimal growth is of paramount importance to them and their food intake must provide sufficient nutrients not only for the maintenance of body tissues but also for growth. During infancy and adolescence children grow extremely rapidly. At these times children are particularly sensitive to energy restriction because of high basal and anabolic requirements. The ability to provide sufficient nutrients parenterally to sustain growth in infants and children suffering from intestinal failure or severe functional
intestinal immaturity represents one of the most important therapeutic advances in pediatrics over the last three decades [1]. Improvements in techniques for nutritional support has resulted in very long-term parenteral nutrition being available for a cohort of patients with very chronic intestinal failure in addition to those who require short-term parenteral feeding in hospital either following surgery or whilst treatment for an underlying enteric disease becomes effective. Children with prolonged intestinal failure have the potential to grow and develop normally and to enjoy a good quality of life within the constraints of their underlying disease [2].

Whilst advances in knowledge of nutrient requirements, improved methods of nutrient delivery and understanding of the prevention and management of complications ensure that parenteral nutrition [3] can be delivered safely and effectively there nevertheless remain areas of uncertainty particularly with regard to weaning from parenteral to normal nutrition. In considering when and how to wean a child back to enteral feeding a number of general factors as well as specific gastrointestinal states need to be considered.

In general parenteral nutrition is required whenever sufficient nutrients cannot be provided enterally to prevent or correct malnutrition or to sustain appropriate growth. Malnutrition in children, in addition to the general effects of impaired tissue function, immunosuppression, defective muscle function and reduced respiratory and cardiac reserve also results in impaired growth and nutrition.

Whilst somatic growth exhibits a bimodal pattern being fastest in infancy, then dropping off and receiving a further spurt around puberty other organs of the body may grow and differentiate only at one particular time. This is particularly true of the brain for which the majority of growth occurs in the last trimester of pregnancy and in the first 2 years of life. Poor nutrition at critical periods of growth results in slowing and stunting of growth which may later exhibit catch-up when a period of more liberal feeding occurs. In adolescence there is a risk of not achieving growth potential if severe and continuous disease occurs and adequate provision is not made for their nutritional needs. The sick child is at the greatest risk of growth failure and nutritional disorder [4].

Neonates and very small infants because of small energy reserves are at a considerable disadvantage compared with older children and adolescents when weaning from parenteral nutrition [1]. In these small infants it is essential to consider carefully whether gastrointestinal function is sufficient for enteral nutrition to adequately support the infant. Thus the time when the infant and child can be weaned from parenteral nutrition will depend both on individual circumstances and the age and size of the infant or child. Some patients will have only required short-term parenteral nutrition following major intestinal surgery, chemotherapy, severe acute pancreatitis, or multiorgan failure in extensive trauma, burns and prematurity. Others will have needed long-term parenteral nutrition when they suffered prolonged
episodes of intestinal failure most often caused by protracted diarrhea of infancy, short bowel syndrome, gastroschisis or chronic intestinal pseudoobstruction.

**Weaning from Parenteral Nutrition**

*General Considerations*

Parenteral nutrition is a potentially life-threatening form of nutritional support; the overriding priority is to wean the child off parenteral nutrition as soon as is possible. Infants and children who have an acute episode of severe intestinal failure with a previously normal gut, e.g. after surgery or during a course of chemotherapy, may when gut function has recovered tolerate the rapid reintroduction of a normal diet. On the other hand, children with primary gut disease will often need the introduction of enteral feed tailored according to the nature and activity of the underlying disease.

In all children the following factors are critical to the success of introducing enteral nutrition:

- Appropriate minimal enteral feeds should be given wherever possible to prevent gut atrophy [5]
- Encourage adaptation and treat aggressively underlying gastrointestinal disease [6–9]
- Reduction of the risk of parenteral nutrition-associated liver disease [2, 10]

The following practical points may ensure success:

- Involve an experienced dietitian and nutrition support team
- Only make one change in treatment at a time to assess tolerance, e.g., when the volume of enteral nutrition is increased, the concentration of the nutrition solution should remain constant
- Maintain central venous access until the child is fully enterally fed
- In those with severe intestinal failure feed volumes should be increased slowly according to tolerance

*Methods of Feeding*

Some children can be weaned straight on to bolus feeds, in others continuous feeding may be required. In these as soon as enteral nutrition can be introduced a liquid enteral feed infused as continuous enteral nutrition over 4- to 24-hour periods, using a dedicated feeding pump and enteral feeding system, should be started. The main advantage of a continuous feed is that the feed can be more easily controlled and adjusted to the guts’ absorptive capacity. The feed should be prepared carefully under hygienic conditions and should not be kept at room temperature longer than 8h. Some children will not tolerate bolus feeds and in these children it may be necessary to use continuous feeding long-term. Although cumbersome this is preferable to
long-term parenteral nutrition as the mortality and morbidity are markedly lower.

Liquid enteral feeds can also be given as bolus or sip feeds either orally or via a gastrostomy or feeding tube. It may be necessary to give the bolus feeds as frequently as 2-hourly while the child is awake and continuously at night. If bolus feeds are needed more frequently, a continuous feed is more practical and should be commenced. Whenever possible bolus feeds should be offered by mouth. Smaller infants should not be woken up to give oral feeds to avoid fatigue. If gastric feeds are poorly tolerated (vomiting/large amounts of feed aspirated) feeding into the jejunum should be undertaken with the help of an expert gastroenterology or nutrition support team, as this is a high risk technique.

Children who rapidly recover intestinal function may be weaned straight on to normal food. Every possible attempt is made to encourage children to eat normally. Spoon feeding should be introduced at the normal age, that means around 6 months of age, even if only small amounts can be offered. Some mothers will find it difficult to accept that their child ceases to eat voluntarily when an adequate amount of enteral feed is infused via an artificial feeding device. Some children may develop severe oral hypersensitivity or have delayed oromotor development which may be associated with gastro-esophageal reflux. Injudicious increases in feed volume or texture often result in a deterioration of their feeding problem [11].

**Types of Feed**

In newborn infants with a short but normal gut expressed breast milk is the preferred form of nutrition to optimize adaptation. Mother's own milk should be given pasteurized when continuous feeding is used but fresh if oral or tube bolus feeds are given.

Children with gastrointestinal disease causing intestinal failure usually require a specially formulated pediatric enteral feed when weaning. Elemental, hydrolyzed protein or whole protein feeds are selected according to the child's ability to tolerate the feed constituents or availability in the case of expressed breast milk. If there is any possibility of persistent intestinal inflammation an appropriate protein hydrolysate or amino acid-based formula should be used [12]. In neonates with short gut syndrome the outcome is improved with breast milk [10] or an amino acid-based formula feed [13, 14]. In both these situations diet may need to be adjusted as there appears to be a high incidence of cow's milk or soy protein intolerance. If at all possible a commercially available complete feed that provides the child's entire nutritional requirements should be used. This reduces the risk of providing an unbalanced diet and the risk of infectious complications.

Modular feeds should only be used when complete feeds appropriate for the individual have not been tolerated. The advantage of a modular feed is that protein, carbohydrate and fat (medium- vs. long-chain triglycerides) can
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each be gradually introduced as tolerated. Electrolytes, vitamins and minerals must all be added according to requirements. Thus the feed is tailored for the individual child. Modular feeds are generally not recommended due to the risk of bacterial contamination; the possibility of accidentally omitting essential nutrients, preparation at home can be complicated, and there may be settling out of the feed constituents when the feed is administered continuously. However, in children with ultrashort bowel syndrome modular feeds may enable improved enteral energy intake and tolerance.

Timing of Weaning
Reduction in the amount of parenteral nutrition may be attempted as soon as the child is stabilized, i.e. intestinal losses from vomiting and diarrhea have been minimized and an optimal nutritional state reached. The underlying intestinal failure should be investigated and treated in a specialist pediatric gastroenterological unit. All children on parenteral nutrition should continue to have a minimal amount of enteral feed to maintain enterohepatic circulation and possibly gut integrity [10, 15, 16] whenever possible. As soon as a small volume of the desired feed is tolerated at low rate, the volume should be increased. The feed should be given at normal concentrations and not diluted, otherwise the child will achieve normal fluid intake without adequate nutrition. The aim should be to maintain a good nutritional intake by decreasing the parenteral feed and increasing the enteral feed by similar amounts. This is best achieved by reducing the parenteral feed slightly faster than the rate the enteral feed is increased. Enteral tolerance is more likely to be achieved by avoiding excessive fluid intake. In children with more severe intestinal failure, enteral feeds may need to be introduced and increased as slowly as 1 ml/kg per 24 h. Parenteral nutrition might be reduced by 5 ml/kg per 24 h every few days. If a chosen weaning strategy fails it is worth trying again, but at a slower pace, e.g. with smaller rate or volume increments.

In children who are stable and thriving on parenteral nutrition at home the quality of life for the family can be vastly improved by removing one parenteral nutrition infusion per week allowing them a night of normal life [17]. If tolerated, further reductions can be made by reducing parenteral nutrition one night at a time over several weeks or months. Weaning can be facilitated by reducing/halving the parenteral nutrition given one night a week and seeing how well the child is the following day. If fluid and electrolyte loss becomes an issue nocturnal provision of an oral rehydration solution via a nasogastric tube may be a solution. In infancy and childhood a night off parenteral nutrition would, usually, only be tried when at least 50% of nutrients are tolerated enterally. The ability to tolerate a night off parenteral nutrition varies according to the underlying disease. A night off is usually well tolerated by children with short bowel syndrome who are stable with improving intestinal function. In children with short bowel, weaning is prolonged in the presence of bacterial overgrowth and associated enteritis [12]. In children with
chronic intestinal pseudoobstruction, especially with ileostomy and major fecal losses, removing one night of parenteral nutrition often leads to a rapid increase in oral fluid and feed intake due to thirst and hunger leading to aggravation of symptoms.

The child’s ability to tolerate the reduction in parenteral nutrition is assessed by checking hydration, weight gain, growth, and blood indices.

Problems that can arise when weaning is not tolerated include D-lactic acidosis due to lactate production from fermentation of nutrients dumped in the colon and distal ileum by the bacterial flora due to the increased intake of enteral nutrition exceeding the absorptive capacity of the small intestine. Although some studies have indicated that bacterial fermentation is more of a problem in the absence of the ileocecal valve [18], this does not always seem to be the case [12]. Such complications may be prevented by manipulating the colonic flora with a low fiber diet, bicarbonates and, sometimes, anaerobic antibiotics (metronidazole) plus probiotics [12]. However in order for this problem not to occur the enteral intake needs to be matched to the ability of the child to digest and absorb the enteral load. Sometimes it may be necessary to reduce the intestinal load and increase parenteral nutrition again whilst treating the underlying disease more effectively or waiting for intestinal adaptation to improve allowing for recommencement or continuation of the weaning process.

Avoiding Feeding Problems

Whenever possible it is important to maintain small volumes of oral feeds and monitor the adequacy of feeding skills, even if the infant or child is established on continuous feeds.

Solids should be started at the usual recommended age for healthy infants when possible. It is best to limit these initially to a few foods that are least likely to have an allergenic effect (especially in intestinal inflammation), e.g. rice, chicken or carrot, and which will be suitable for the underlying gastrointestinal disease, e.g. low sucrose/low in long-chain triglyceride fat or low fiber in short bowel and/or extensive colon resection.

When food is introduced, the aim is to encourage normal textures for age [11]. Even if the amount and range of foods are limited, introducing normal food will promote normal feeding behavior. Encouraging oral feeding will help to prevent feeding problems which can continue for many months or even years.

Even in younger infants, bolus feeds may have beneficial psychological and social effects. For example, the mother will feel that she is doing something to help her sick child. Maternal bonding may be improved by the close contact between mother and child. Feeding by mouth should be a pleasurable event for both mother and child.
References


Discussion

Dr. Fakhraee: Most neonatologists are concerned with necrotizing enterocolitis in premature babies. What is the incidence of necrotizing enterocolitis with minimal enteral feeding; is it decreased or increased or is there no change in the incidence of necrotizing enterocolitis?

Dr. Milla: Clearly necrotizing enterocolitis is a problem in premature infants. I am not aware of formal studies addressing the point that you have made. If you look at series of patients with necrotizing enterocolitis it is clear that it started as soon as nutrients were introduced into the bowel. I can’t answer your question as to
what the figures are, but the advantages of minimal enteral nutrition outweigh the disadvantages.

_Dr. Jochum:_ You did not touch on the point of nonnutritive sucking in neonates. Could you comment on the use of probiotics in neonatal nutrition?

_Dr. Milla:_ As far as nonnutritive sucking is concerned there is certainly evidence to show that where you use nonnutritive sucking in a premature infant you will be able to introduce feeds sooner than if you don't give them that practice. It has more to do with gut motility than the ability of the gut to absorb food. Nonnutritive sucking is useful in neonates in terms of trying to get them to tolerate particularly oral feeds. As far as probiotics are concerned I am not a neonatologist, I don't have any experience of that. These are rather severe diseases that result in the need of parenteral nutrition. Probiotics have some effect but not a major effect, and they have never enabled us to get them off parenteral nutrition and to wean them onto enteral feeds.

_Dr. Balanag:_ Can you elaborate on the use of occult blood as a screening method for starting enteral feeding?

_Dr. Milla:_ If you use occult blood in most patients who have an enteropathy it would be found to be positive a lot of the time. I am not a great fan of occult blood tests because I think most of them are far too sensitive. Many patients with inflammatory enteropathy bleed. I don't use occult blood because it is not going to tell me anything which is going to alter my management of that individual. On the other hand if there is obvious blood in the stool then that is a significant amount. The majority of patients who have this sort of disease lose more blood from the investigations than the disease. I have never found this test helpful.

_Dr. Ruemmele:_ It is a difficult topic and your experience is helpful in developing a strategy to wean these patients from parenteral nutrition. Could you comment on the role of bacterial flora in this context? I am not talking about prebiotics but the commensal bacteria of the flora. For instance bacterial overgrowth is seen in children with short bowel; once these children are off parenteral nutrition the situation can be very dangerous. The simple use of antibiotics for a bacterial infection may cause a loss of intestinal autonomy and parenteral nutrition must be restarted. Could you comment on that?

You introduced your topic saying that the major function of the small bowel is absorptive. I would add, and this is my personal view, that the small bowel is also a major immune organ. I would not just reduce it to its absorptive function.

_Dr. Milla:_ The gut is the major immune organ of the body and the reason for this is that it has to be permeable to let all these nutrients through. Because of this it will let through a lot of other things which are very injurious. Bacteria are a problem and there are at least 3 situations in which they are particularly important. If there is a short gut and anastomosis has occurred or adaptation has taken place, if there is a stricture to the anastomosis then subacute obstruction can occur. If there is excessive adaptation and the bowel is largely dilated then motor activity results in ineffective transit and bacterial overgrowth occurs. This is one of the reasons tapering enteroplasty or stricture resection can be extremely helpful in these patients. There are other conditions in which bacterial overgrowth occurs because the immune system is defective in some way, and in patients who have primary immunodeficiency as well as AIDS patients, it may be that this is the cause of the bacterial overgrowth, and it needs to be treated in a variety of ways. Antibiotics are one way, and Dr. Sorensen told us about oral immunoglobulin, which is frequently used in patients with neuromuscular disease and functional obstruction to try to clear their bowel. The biggest problem with these patients is that muscle disease may worsen the functional obstruction. The inflammatory process that caused the bacterial overgrowth results in alterations of muscle cell function. They start to participate as amateur antigen-presenting cells in
the inflammatory process. Two things which appear to be contradictory need to be
done: treat the bacterial overgrowth and treat the inflammation.

Dr. Hendarto: We have a few cases of functional intestinal obstruction. How long
should the patient be on parenteral nutrition before giving hypoallergenic formula?

Dr. Milla: Severe neuromuscular disease that causes functional obstruction is not
easy to manage and if obstruction continues then sufficient nutrition to support them
becomes difficult. Parenteral nutrition is the only practical way of getting many of
these patients over these prolonged episodes of ileus. On the other hand in some of
the milder diseases, the episodes of functional obstruction are not very long lasting. As
soon as stomach emptying becomes more normal, my practice is to start introducing
feed when the nasogastric aspirates drop below 150 ml/day. As soon as this occurs
they start passing wind, which is the time to introduce a continuous whey protein
hydrolysate. There is very good experimental data showing that whey proteins are
emptied from the stomach faster than all other whole proteins with the exception of
human breast milk. It is emptied at about the same rate as human breast milk, so we
use whey proteins in preference to any other form of hydrolysate for this purpose.

Dr. Rivera: Regarding the issue of feeding methods for premature babies, the abil-
ity to suck and some of their reflexes are very important for them to feed. An alterna-
tive to nipple feeding is a small cup which enables us to feed babies up to 27 weeks of
gestational age. We are very successful with the use of this small cup, and we don't
have any extra loss of calories.

Dr. Shaaban: In the procedure of adaptation, when changing from parenteral to
enteral nutrition, what form of the nutrient do you deliver, liquid, semisolid or solid
food? If you take into consideration the gastric emptying time and the density of the
nutrients, would you still chose the continuous method of delivery or would you pre-
fer bolus feeding at a longer interval?

Dr. Milla: Over the years we have found continuous liquid feed to be most suc-
cessful, which is why I was suggesting that. All of the other things that you suggest
depend entirely upon there being virtually normal motor activity, particularly in the
stomach and duodenum. The problem with most of these patients, particularly if they
have inflammatory enteropathy, is that motor activity won't be normal and stomach
emptying will not be sufficiently smooth. Coordinating gastric with duodenal activity
will enable the supply of sufficient nutrients but once the ability to empty the stomach
is exceeded then the stomach distends and vomiting starts. I am very convinced that
using continuous liquid feeds is the simplest, safest and best way to get the most cal-
ories into an infant. Parents in particular think because their child is being given a liq-
uid that they are not having food, which is not the case, and they must be convinced
that it is the best way forward.

Dr. Bojadzieva: My question is whether partial parenteral nutrition and partial
enteral nutrition will perhaps reduce bacterial translocation, especially for premature
babies and very low birth weight babies?

Dr. Milla: If I was being very provocative I would say forget about bacterial translocation because the evidence that it occurs is not very good. If you think about
the structure of the gut and its immune system and the lymphatic drain into the gut,
you would realize that the notion of flooding the vasculature with bacteria is probably
not a sustainable idea. There is some evidence to suggest that it might take place. I
haven't really found it to be a major problem and we send home a lot of patients on
parenteral nutrition. They all have active disease. The one thing that marks them out
is that they don't get sepsis. One of our patients had the same line in for 10 years with-
out infection. It has all to do with how the lines are looked after and I don't worry
about things like bacterial translocation. Sometimes you need to do both parenteral
and enteral feeding and there is no doubt that if you have a patient who requires
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long-term parenteral nutrition and you can get them onto at least 30% of the calories enterally, they are a lot easier to manage. The majority of our patients are treated with a mix of parenteral and enteral feeding. I try to avoid total parenteral nutrition, because it is bad news long term.

Dr. Fakhraee: Regarding Dr. Rivera’s comment on cup feeding; this is recommended by WHO and UNICEF to feed premature babies because bottle feeding causes a phenomenon called ‘nipple confusion’. Babies who are only bottle fed may not be able to breastfeed, and because of that WHO recommends cup feeding. We also have experience with cup feeding in very small premature babies and I think it is a good practice.

Dr. Milla: If you want premature infants to grow to their potential I doubt that using a normal formula supplies babies with sufficient calories to survive. But what is the appropriate standard? All the work that people like Dr. Lucas have done would suggest that the standards we have for the growth of premature infants are probably not right, and a lot more thought needs to be put toward how this is done. Survival is one thing, growth to their potential is another thing.

Dr. S. Koletzko: I have a question with respect to your study with the new formula. You said they were young children with inflammatory enteropathy. Could you please tell us more about their diagnoses; did you also include patients with short gut syndrome?

Dr. Milla: There were some short gut patients but basically they were all patients who had a small intestinal inflammatory enteropathy. The enteropathy could have had many different causes. Some had mild autoimmune disease; we excluded patients who required immunosuppression.

Dr. S. Koletzko: Also patients with long-term diarrhea?

Dr. Milla: They all had long-term diarrhea otherwise they would never have come to us. These were patients who would have been treated in a district general hospital.