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10. Organisational Aspects of Hospital PN

METHODS

Literature Search

Timeframe: publications from 1992–2003, in addition relevant publications from 1980–1992 and 2005 were considered.

Type of publications: randomised control trials, case control or cohort studies, case series, case reports, reviews (expert opinion).

Key Words: parenteral nutrition, computer assisted prescribing, nutritional care teams, nutrition support teams, monitoring, nutritional assessment, nutritional support, anthropometry, growth monitoring, intravenous therapy, infusion pumps, filters, nutrition team.

Language: English.

ORDERING AND MONITORING PARENTERAL NUTRITION IN HOSPITAL

Introduction

The process of providing parenteral nutrition (PN) is far from being evidence based (1,2). The ordering process, in particular, has not been investigated systematically, and much more attention has been focused on defining the requirements for various nutrients. The aim of the following summary is to provide a framework for the nutrition team member responsible for ordering PN.

The purpose of PN is to correct or prevent nutritional deficiencies when adequate enteral feeding is precluded by impairment or immaturity of gastrointestinal function. The PN order should be part of an overall nutritional care plan. Mandatory steps before the initiation of PN include a thorough nutritional assessment (medical and dietary history, physical examination, laboratory data, etc). Probable duration of PN administration should be estimated, and nutritional goals set. The process is dynamic, and the order should take into account changes in nutritional and clinical status.

PN Ordering

There is little evidence of efficacy from randomised control trials of PN improving outcome (3). Accepted goals for PN are prevention of weight loss, maintenance of normal growth, and promotion of catch-up growth. Essential pre-requisites to the ordering process include secure venous access, and the availability of medical, nursing, dietetic and pharmacy staff skilled in the management of PN and its complications. Clinical pathways have been designed to facilitate the management of PN in children. These pathways include developing a nutrition support team, and structuring a comprehensive set of clinical, laboratory, and management parameters to ensure adequate PN administration (4,5). Bowman et al have demonstrated that monitoring compliance with such a nutrition support algorithm can improve quality of care.

Delivery of Parenteral Nutrition

PN may be given via a peripheral or central venous catheter (PVC/CVC) depending upon the availability of venous access and the osmolality of the solution (for further discussion on this topic see chapter on venous access). Weight gain is more commonly achieved with central versus peripheral infusion (6). In certain circumstances PN may be given in dialysis solutions (7) or via ECMO (8).

Individualised Versus Standard Parenteral Nutrition

Time pressures on the pharmacy, limitations of resources and cost considerations make the use of standard solutions an attractive option. These standard formula do not meet all the requirements of newborns, infants and children (9,10), although even in those units relying on individualised prescribing, there is some scope for their use in stable patients (11). A study comparing short term standard solution (fixed amino acid/glucose ratio) with a computer generated individualized prescription, taking enteral intake and additional fluids into account, did not find any differences in the weight gain of premature infants (12). In contrast, a randomized control study comparing individualised versus standard PN formulation in premature infants demonstrated higher intakes of amino acids, lipids and energy, with greater weight gain, in the group receiving individualised PN (13). However, the difference in caloric intake and weight gain might not be attributable to the administration of standard solutions per se, but to the more intensive monitoring assisted by pharmacists in the group receiving individualized PN. Uncritical use of standard formulations, particularly over longer periods of time, may be detrimental to growth and development (LOE 4).

Computer Assisted Prescribing

The ordering process is time consuming, necessitates knowledge and experience, and involves the risk of fatal

errors (14). Computer programs for ordering PN are widely used (14–19). One such program reduced the time needed to calculate a nutrition plan from a mean of 7.1 minutes to 2.4 minutes, with errors in calculation being corrected interactively and reduced from 56% to 22% (14). In another study, the time required to write and deliver PN orders was significantly lower using computer rather than manual methods (1.4 ± 0.2 vs 4.5 ± 0.5 minutes; $P = 0.0001$), and the use of computer ordering lead to significant improvements in the nutrient composition of the PN for energy, protein, calcium, and phosphate (20). In addition, alkaline phosphatase concentrations improved, and caloric and protein goals were achieved sooner, compared with the manual method of ordering (20). Available programs can provide rapid definition of the nutrition plan with reduced likelihood of providing excessive glucose and energy (21).

Initial Prescription

Fluid requirements, nitrogen and energy needs should be established and the total fluid volume available for PN solutions determined. Details of water and nutrient requirements at different ages are given elsewhere in this publication.

Monitoring

Suggested assessment before PN initiation is given in Table 1. Selection and frequency of biochemical monitoring parameters will reflect clinical and nutritional status in addition to duration of feeding. For example, patients with abnormal fluid losses or organ failure require more frequent monitoring, as do those who are under weight and at risk of re-feeding syndrome. Sudden, unexpected and serious biochemical abnormality in stable patients without severe malnutrition when receiving PN is uncommon (22). Nursing observations will include catheter inspection together with temperature and heart rate; periodically the nutrition team should review nutritional status and goals of nutritional intervention. Quality indicators of a PN service include regular audit of PN utilization/wastage, complications (particularly CVC sepsis), and communication with pharmacy (23).

TABLE 10.1. *Suggested assessment before ordering PN for infants and children* depending on clinical status (LOE 4)*

- complete diet history
- anthropometry (weight, height/length, head circumference)
- full blood count (including platelets and differential white count)
- electrolytes
- urea/creatinine
- glucose
- calcium/phosphate
- albumin (or pre-albumin)
- liver function tests
- cholesterol/triglycerides
- urinary glucose and ketones

*These parameters are examined 2–3 per week initially, and the frequency is ''tapered'' based on the patients' clinical status and long term goals. When PN extends beyond three months, trace elements, ferritin, folate, vitamin B_{12}, thyroid function, clotting, and fat soluble vitamins are often measured.

TABLE 10.2. *Review of nutritional status undertaken during parenteral nutrition*

Weight for height (% expected): 100 × weight, divided by 50th centile weight for observed height when plotted on 50th centile.
Triceps skin folds thickness (27)
Mid arm circumference (28)
Arm fat area
Mid arm circumference: head circumference ratio (29)

Recommendations for Ordering and Monitoring Parenteral Nutrition in Hospital

- Nutritional support algorithms should be followed for the ordering and monitoring of parenteral nutrition. **GOR D**
- Compliance with the algorithm should be monitored to improve quality of care. **GOR D**
- Although individualized PN is preferred, with adequate monitoring and the scope for addition of deficient electrolytes and nutrients, standard PN solutions can be used for short periods of up to two weeks (LOE 4). This is potentially more useful in newborn infants when providing PN soon after birth, and when a range of standard regimenns to suit different clinical conditions might be available. **GOR D**
- Computer assisted prescribing of PN should be encouraged, as this can save time and improve the quality of nutritional care. **GOR B**

NUTRITIONAL ASSESSMENT

Introduction

A multidisciplinary nutrition support team should monitor the process of parenteral nutrition. Nutritional status can be assessed using simple and non-invasive measurements of body dimensions (anthropometry). Appropriate equipment and trained staff ensure consistency. Early nutritional assessment identifies children at nutritional risk. Nutritional intervention minimizes wasting and restores body cell mass, optimises nutritional status, improves quality of life and prolongs survival. The aim of a nutritional assessment is to establish baseline subjective and objective nutritional parameters (24) by which to judge the effects of parenteral nutrition, and is divided into clinical examination, anthropometry, laboratory indices, and assessment of dietary intake. It should also identify specific nutritional deficits, determine nutritional risk factors for individual patients,

establish nutritional needs, and identify medical and psychosocial factors influencing the prescription and administration of parenteral nutrition (25,26).

Clinical Examination

Clinical examination provides an important overall impression of health. Severe nutritional deprivation is easily detectable in most instances. Through medical, dental history and physical examination, signs suggestive of nutrient deficiency or excess should be documented and supported with biochemical, anthropometric and dietary evaluation.

Anthropometry

Anthropometric data includes height, length, head circumference (under 3 years old), current weight, ideal weight and weight/height ratio.

Standardised nutritional assessments should be accurately recorded and form the basis for PN audit. Serial data show changes and rates of changes, giving a dynamic picture of progress. Regular measurements of height, weight and head circumference with comparison to normal values for chronological age using percentile charts remain the most useful assessment tools for nutritional interventions ((30) (LOE 4)). Accurate chronological ages are essential when using growth charts (31,32). Expression of measurements in terms of standard deviation scores allows changes in rates of growth with time to be detected more easily than from observation of percentile charts. Measurements of skin fold thickness and mid arm circumference, along with calculation of mid arm fat area and mid arm muscle area, reflect body fat and protein. Skin fold thickness provide an index of body energy stores and is used in conjunction with 'weight for height' to assess body composition (33).

Laboratory Assessment

Laboratory investigations provide an objective assessment of nutritional status and are useful in the detection of early physiological adaptation to malnutrition and the recognition of specific mineral and vitamin deficiencies (34). Laboratory data should be reviewed and documented. A number of biochemical measurements, usually of serum proteins, are used. None is ideal, as they have differing half lives and are all affected by other non-nutritional physiological and pathologic states.

Dietary Intake

Subjective assessment must include a dietary record that focuses on nutritional history. Recent changes in dietary intake, review of enteral feeds and parenteral nutrition, gastrointestinal symptoms, cultural and religious dietary prescriptions, as well as concurrent medical and surgical problems that may affect nutritional assessment should be documented.

Recommendation

- Accurate measurements and clinical evaluation of patients receiving PN should be undertaken 2–3 times weekly by a skilled practitioner (e.g. Dietitian or Nutrition Support Nurse). **GOR D**

WEANING FROM PN

Children with an acute episode of severe intestinal failure e.g. post surgery or during a course of chemotherapy may tolerate rapid reintroduction of a normal diet. Children with primary gut disease need the method of feed introduction tailored according to the underlying disease.

The following factors should be considered when introducing enteral nutrition:

- Appropriate minimal enteral feeds should be given wherever possible to prevent gut atrophy ((35) (LOE 3)), encourage adaptation ((36,37) (LOE 3), (38) (LOE 4)), ((39) (LOE 4)) and reduce the risk of PN-associated liver disease ((40) (LOE 3)). In newborn infants with short gut expressed breast milk is the preferred nutrition to optimise adaptation. The mother's milk should be given either fresh (in case of small bolus feeding) or pasteurised (in case of continuous feeding).
- Always 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.
- In severe intestinal failure feed volumes should be increased slowly, according to digestive tolerance.
- An experienced dietitian/nutrition support team should be involved.
- Central venous access should be maintained until the child can be fully fed enterally.

The initial over-riding priority is to wean the child off PN since there are life-threatening risks to continuing it. Enteral nutrition can be introduced as liquid enteral feed infused as continuous enteral nutrition over 4 to 24 hour-periods, using a volumetric pump via an artificial feeding device. The main advantage of a continuous feed is that full use of the intestinal tract is made, particularly if given over 24 hours. The feeding should be prepared under strict hygiene condition and should not be kept at room temperature longer than 8 hours. To reduce the risk for *Enterobacter sakazakii* infetion a ready made liquid formula is preferred over a powdered formula. Although continuous feeding is not practical in the long-term, it is often necessary as an initial manoeuvre.

Some children can be weaned straight on to bolus feeds. Liquid enteral nutrition can be given as bolus or sip feeds

either orally or via an artificial feeding device. This is most likely to be the case when the intestinal tract has significantly improved since the need for PN arose. It may be necessary to give the bolus feeds as frequently as 2-hourly while the child is awake and as an option continuously at night. If they are needed more frequently, a continuous feed should be commenced. Bolus feeds should be offered by mouth whenever possible. 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 considered. The decision should be taken only by an expert gastroenterology team, as this is a high risk technique.

Children who rapidly recover intestinal function may be weaned straight on to normal food. However, if there is any possibility of persistent intestinal inflammation, diet may need to be adjusted. For example, the prognosis of neonates with short gut syndrome is improved with breast milk ((40) (LOE 3)) or an amino acid based formula feed ((41) (LOE 3)) as there appears to be a high incidence of cow's milk or soya protein intolerance.

Every possible attempt is made to encourage children to eat normally. Spoon feeding should be introduced at normal age, that means around 6 months of age, even if only small amounts can be offered. Some children may develop severe oral disability which may be associated with gastro-oesophageal reflux (42) that worsens with an increase in feed. 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.

Recommendations

- Rather than enteral starvation, minimal enteral feeds should be given whenever possible. **GOR D**
- An experienced dietitian/nutrition support team should be involved. **GOR D**
- When introducing enteral feeding only one change in treatment at a time should be made to assess tolerance. **GOR D**
- In severe intestinal failure feed volumes should be increased slowly, according to digestive tolerance. **GOR D**
- Enteral feeding can be introduced as liquid enteral feed infused as continuous enteral nutrition over 4 to 24 hour-periods, using a volumetric pump via an artificial feeding device. **GOR D**
- Liquid enteral nutrition can be given as bolus or sip feeds either orally or via artificial feeding device, if tolerated. **GOR D**
- Children who rapidly recover intestinal function may be weaned straight on to normal food. **GOR D**

Types of Feed

Children with a primary gastrointestinal disease causing intestinal failure usually require a specially formulated paediatric enteral feed when weaning. 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.

Elemental, hydrolysed 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. Short bowel syndrome is an indication for hydrolysed diet, at least in children <1 year, during the first months of the adaptive period. There is evidence that an amino acid based feed might be even better tolerated ((41) (LOE 3), (43) (LOE 3)). A high osmolarity may be of disadvantage.

Modular feeds should only be used when feeds appropriate for the individual have not been tolerated. The advantage of a modular feed is that protein, carbohydrate and fat (MCT vs LCT) can each be gradually introduced as tolerated. Electrolytes, vitamins and minerals must all be added according to requirements. A tailor made feed can be produced 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 ultra short bowel syndrome modulare feeds enable to improve and increase the enteral energy intake and tolerance.

Recommendation

- Children with a primary gastrointestinal disease causing intestinal failure usually require a specially formulated paediatric enteral feed when weaning. **GOR D**

When to Wean

Reduction in the amount of PN may be attempted as soon as the child is stabilised i.e. intestinal losses from vomiting and diarrhoea have been minimised and an optimal nutritional state reached. The underlying intestinal failure should be investigated and treated in a specialist unit with specialist expertise in paediatric gastroenterology.

All children on parenteral nutrition should continue to have a minimal amount of enteral feed to maintain enterohepatic circulation and possibly gut integrity ((44) (LOE 3), (40) (LOE 3), (45) (LOE 3)) 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 hours. Parenteral nutrition might be reduced by 5 ml/kg per 24 hours every few days. If a chosen weaning strategy fails it is worth trying again, but at a slower pace e.g. with smaller rate increments.

In children who are stable and thriving on PN at home, many experts try to remove one PN infusion per week to improve the quality of life for the family. If tolerated, further reductions are made by reducing one night at a time over several weeks or months. Weaning can be facilitated by reducing/halving the PN given one night a week and seeing how well the child is the following day. If fluid and electrolyte loss is the main issue noctural application of a rehydration solution via a gastric tube may be a solution. In older children it may be possible to reduce the PN by a night per week even when they are still having virtually all their nutrition intravenously. In infancy a night off would, usually, only be tried when at least 50% of nutrients are tolerated enterally. The ability to tolerate a night off PN 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 (42). In children with chronic intestinal pseudo-obstruction, especially with ileostomy and major faecal losses, removing one night of PN often leads to a rapid increase in water/feed intake leading to aggravation of symptoms.

The child's ability to tolerate the reduction is assessed by checking weight gain, growth, and blood indices (see Complications chapter).

Problems that can arise when weaning is not tolerated include D-lactic acidosis due to lactate production from fermentation of non absorbed nutrients by the bacterial flora in the colon and distal ileum due to the increased intake of enteral nutrition. Although some studies have indicated that bacterial fermentation is more of a problem in the absence of the ileocaecal valve ((46) (LOE3)), this does not always seem to be the case ((42) (LOE3)). Such complication may be prevented/treated by a low fibre diet, bicarbonates and, sometimes, anti anaerobic antibiotics (Metronidazole) plus probiotics ((42) (LOE 3)). Sometimes it is necessary to reduce intestinal load and increase PN again whilst waiting for intestinal adaptation to improve allowing for recommencement or continuation of the weaning process.

Recommendations

- Enteral nutrition should be given at normal concentrations and not diluted. **GOR D**
- PN should be reduced by similar amounts or slightly more than the increase in EN. **GOR D**
- If a chosen weaning strategy fails, trying again more slowly is an option. **GOR D**

Psycho-Social and Developmental Aspects of Feeding

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, carrot, and which will be suitable for the underlying gastrointestinal disease e.g. low sucrose/low in LCT fat or low fibre in short bowel and/or extensive colon resection.

When food is introduced, the aim is to encourage normal textures for age ((47) (LOE 4)). Even if the amount and range of foods are limited, introducing normal food will promote normal feeding behaviour. 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 psychologic 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 mother and child.

Recommendation

- Whenever possible small volumes of oral feeds should be maintained. **GOR D**

INFUSION EQUIPMENT AND INLINE FILTERS

As with most parenteral therapy, one of the greatest hazards to patients during administration of nutrient solutions arises from the risk of free flow or poor rate control of the infusion. To the potential risks of fluid overload and heart failure are added complications such as hyperglycaemia, aminoaciduria and biochemical imbalance. A modern infusion pump is preferred with its capability to accurately deliver at low flow rates (48,49). Alarm functions are necessary, but sensitivity is

often limited at low rates of flow. The ability of children to learn to manipulate devices should not be underestimated. If pumps are not available, the use of portable, battery powered drop counting devices can provide effective warning of free flow conditions.

PN solutions contain particulate matter (50) and biochemical interactions can lead to chemical precipitates and emulsion instability. PN solutions are also media for microbiologic contamination. Localised tissue damage at the infusion site is related both to osmolarity of the solution and particulate contamination (51). The routine use of inline filtration has been advocated. Some endotoxin retaining 0.22 μm filters allow cost savings through extended use of the administration set. With appropriate filters, sets can be used for 72–96 hours. Many solutions are stable for extended hang-times but explicit stability advice should be sought from the manufacturer or a competent independent laboratory. Filter blockages indicate a problem with the solution, not the filter, and must be thoroughly investigated.

Recommendations

- All PN solutions should be administered with accurate flow control. The infusion system should undergo regular visual inspection. Peripheral infusions should be checked frequently for signs of extravasation. The pump should have free flow prevention if opened during use, and have lockable settings. **GOR D**
- All PN solutions should be administered through a terminal filter. Lipid emulsion (or all-in-one mixes) should be passed through a membrane of pore size around 1.2–1.5 μm. Aqueous only solutions should be passed through a filter of 0.22 μm. **GOR D**

NUTRITION SUPPORT TEAMS

A multidisciplinary nutrition support team (e.g. doctor, nurse, dietitian/nutritionist, pharmacist, possibly others) has an important role in coordinating optimum nutritional care, educating staff, developing guidelines, promoting research (52) and reducing inappropriate PN use ((53) (LOE 3)). A specialist clinical nurse has been shown to reduce catheter related blood stream infection rates in a number of different studies involving adult patients (54–60). Staff training by a nutrition nurse has also been shown to reduce the prevalence of catheter sepsis on a busy neonatal surgical ward ((61) (LOE 2)). Insertion of central venous catheters by an experienced physician is associated with a reduced risk of complications (60,62). The implementation of nutrition support teams has been recommended by the ESPGHAN Committee on Nutrition (63).

Recommendation

- Supervision of parenteral nutrition patients necessitates a multidisciplinary nutritional support team as this is associated with decreased use of inappropriate PN, and decreased metabolic and catheter related complications. **GOR D**

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