Approach to Nutrition Support: Parenteral Nutrition

Developed by Sierra Casey and Dr. Jason Silverman for PedsCases.com.
November 4, 2021

Introduction

Hello! My name is Sierra Casey and I am a 4th-year medical student at the University of Alberta. This podcast was produced with the guidance of Dr. Jason Silverman, a Pediatric Gastroenterologist at the Stollery Children's Hospital, and an Assistant Professor of Pediatrics at the University of Alberta.

This podcast will focus on parenteral nutrition. Parenteral nutrition or "PN" is nutrition support that is delivered directly into the bloodstream. It contains all of the essential micro- and macronutrients, along with water. Total parenteral nutrition or "TPN" describes parenteral nutrition as the sole form of nutrition that a patient is receiving. This podcast is the second part of a two-part series of on nutrition support. If you haven't listened to the first part on tube feeding yet, go check it out!

Learning objectives

By the end of this podcast, listeners should be able to:

1. List common indications for and contraindications to parenteral nutrition.
2. List the components of parenteral nutrition including protein, carbohydrate, fat, fluid, and micronutrients.
3. List the different routes by which parenteral nutrition can be administered.
4. Identify some of the common and serious complications associated with parenteral nutrition and explain how to monitor for and prevent complications.

Let's start with a case.

You are on your pediatric oncology rotation. One of the patients currently admitted to the oncology ward is Emma, a 3-year-old girl who is undergoing chemotherapy treatment for Non-Hodgkin lymphoma. During her admission she has struggled with nausea and vomiting and has been able to take very little by mouth. She is on maximal antiemetic therapy. Three days ago, you and your preceptor decided to start her on tube feeds via a nasogastric tube to provide her with nutrition support while she was unable to eat. However, this morning the bedside nurse tells you that despite being on continuous tube feeds she continues to vomit up to 8 times a day. How can you support her nutritionally during her chemotherapy if she is unable to tolerate her tube feeds? We will come back to this case at the end of the podcast.

Indications for parenteral nutrition

Parenteral nutrition is indicated in patients who cannot tolerate oral nutrition or tube feeds for a prolonged period of time. Generally, if a patient is going without enteral nutrition for 4-5 days or more in older children, or 2-3 days in infants, you should consider starting parenteral nutrition. There are many reasons why a patient cannot tolerate enteral nutrition. While full discussion of each of these conditions is outside the scope of this podcast, we will briefly discuss some common indications for parenteral nutrition.

To start off, premature newborns often require parenteral nutrition if they cannot tolerate sufficient volumes of tube feeds. Some conditions in premature babies such as necrotizing enterocolitis also preclude any tube feeding nutrition and therefore make parenteral nutrition necessary. Patients who require bowel resections due to necrotizing enterocolitis may also require parenteral nutrition if they develop short gut syndrome, where the remaining bowel is too short to absorb sufficient nutrients. Long term parenteral nutrition may be required in patients with short gut syndrome.

For children with intractable nausea and vomiting, the first step, after medical therapy, would be to try tube feeds to maintain their nutrition status. However, if the patient's nausea and vomiting is still uncontrolled and they cannot tolerate tube feeds, parenteral nutrition is indicated.

Some other reasons why patients may require parenteral nutrition include toxic megacolon, neutropenic enterocolitis (often called typhlitis), Hirschsprung's enterocolitis, or severe mucositis in the context of chemotherapy. Patients who require surgery for structural abnormalities of the GI tract may also require parenteral nutrition prior to repair of the structural abnormality, or in the acute postoperative period.

Contraindications to parenteral nutrition

While there are very few absolute contraindications to parenteral nutrition, there are a number of situations in which parenteral nutrition is not indicated. Parenteral nutrition should be avoided in patients whose intestinal tract is functioning and who are able to be fed by tube feeding or orally. A general rule of thumb is that if the patient has a working gut, use it! Parenteral nutrition is generally not indicated if it's use is intended for less than 5 days. When possible, parenteral nutrition should also be avoided in patients with acute pancreatitis. Parenteral nutrition should also not be used in patients with severe fluid, electrolyte, or metabolic imbalances, where infusion of parenteral nutrition could worsen these problems, until they are corrected.

Nutritional content of parental nutrition

Now that you know who needs parenteral nutrition, let's talk about what's in it. You may remember that the main macronutrients in any diet, enteral or parenteral, are protein, carbohydrate, and fat. Because your patient isn't eating, all of these nutrients need to be present in the parenteral nutrition solution. Let's talk about each one individually.

Protein

Protein in parenteral nutrition is delivered in an amino acid solution. Generally, a 2.5% amino acid solution is used in children less than 6 years old, while a 4% solution is used for children older than 6 years old. When calculating a parenteral nutrition recipe, we use recommended grams of the component, per kilogram body weight, per day for calculations. The typical recommended maximum protein that can be administered in a day ranges from 3.5 g/kg/day in premature infants down to 1.5 g/kg/day in adolescents. For children who are well-nourished, without kidney disease, and with no concerns about refeeding syndrome, you can start at the full goal amount of protein when starting parenteral nutrition. These amounts may be higher to meet increased requirements due to burns or injuries, or in specific disease states.

Carbohydrates

The main carbohydrate source in parenteral nutrition is a sugar called dextrose. When administering parenteral nutrition, dextrose and amino acids are often combined in solution and infused together.

The rate of infusion of dextrose is limited by several factors. Firstly, high rates of dextrose infusion can cause hyperglycemia. The infusion rate needs to be titrated up slowly to allow the patient's own insulin production to adjust. Secondly, special care must be taken when using a peripheral IV to administer parenteral nutrition. When high concentrations of glucose and other electrolytes are administered through an IV, this can cause phlebitis, or inflammation of the vein. To avoid this complication, you should generally keep the concentration of the glucose solution below 10%. The maximal glucose infusion rate, or GIR, is lower in children than infants. Aim for 6-11 mg/kg/min in infants and 2-6 mg/kg/min in children.

Fats

Fats, also called lipids, are more calorie-dense than protein and carbohydrate, providing 9 kcal/g. Usually fats are delivered as a 20% emulsion, which means 2 kcal and 0.2 g of fat per mL. Generally, a lipid emulsion is delivered as one solution, and amino acids and dextrose are combined in a second solution.

The most common type of lipid emulsion used in parenteral nutrition is called Intralipid, which comes from soybeans. In infants and children with intestinal failure and associated liver disease, or those who require a longer duration of parenteral nutrition, a product called SMOF may be used. SMOF stands for Soy, Medium chain triglyceride, Olive and Fish oils. In patients with severe intestinal failure-associated liver disease, a special fish-oil based lipid emulsion called Omegaven may also be used. When calculating a parenteral nutrition recipe, fat should make up less than 40-50% of calories for infants and 30-40% of calories for children.

Micronutrients

In addition to macronutrients that provide calories, patients receiving parenteral nutrition also need micronutrients in varying amounts depending on their age and weight. Electrolytes, vitamins, and minerals are provided in the PN solution. Standard parenteral nutrition solutions generally have appropriate amounts of electrolytes and vitamins, but it is important to do the math and adjust as needed to ensure that your patient is getting sufficient amounts.

In summary, parenteral nutrition contains protein and carbohydrates in the form of amino acid and dextrose solutions, which are often combined together. Fats are delivered as a separate lipid emulsion. Vitamins and minerals are also added to the PN solution. It's important to remember that the last essential component of PN is the free water that the nutrients are delivered in. This becomes important when calculating how much of each solution to give, without giving too much fluid, while also considering solution osmolality.

Routes of administration for parenteral nutrition

Once you decide that a patient needs parenteral nutrition, you need to think about how it will be administered. There are three main routes to consider: peripheral IV, peripherally inserted central catheter or PICC, and central venous line. The choice of administration route is mainly determined by caloric need and anticipated duration of therapy. More concentrated solutions mean more calories in a smaller volume of fluid. This is especially important when providing parenteral nutrition for a child who has high caloric needs but also a need to restrict total fluid intake, for example in cardiac conditions. It is also important to consider the length of time that parenteral nutrition will be necessary for, as well as the risk of line infections with each method.

A peripheral IV can generally be used for parenteral nutrition in a well-nourished infant or child who is expected to require parenteral nutrition for less than 2 weeks. They can also be used in patients who only require partial nutrition support, who may be getting some nutrition from tube feeds. Again, peripheral IV's can only be used to infuse more dilute solutions, as higher concentration solutions administered into a peripheral vein can cause phlebitis, or inflammation of the vein.

Low concentration parenteral nutrition limits the number of calories that can be delivered. When a patient needs more calories without using larger volumes of fluid than the patient can tolerate, a central line is required. Central lines deliver nutrition directly into large vessels such as the superior vena cava or inferior vena cava. Peripherally inserted central catheters or “PICC lines” are long catheters threaded through a peripheral vein into a large central vein. Central venous lines are inserted directly (usually by an interventional radiologist or surgeon) into a large vein and threaded into the SVC or IVC. PICCs are generally easier to insert and pose less risk of infection. However, PICCs are not as durable as other central lines. Both PICCs and central venous catheters allow higher concentrations to be delivered but come with a higher risk of line infections than peripheral IVs.

Complications of parenteral nutrition

In general, complications of parenteral nutrition can be divided into catheter-related, or those that are related to the line itself, and non-catheter-related.

Catheter-related complications

Most children requiring total parenteral nutrition will require a central line. Insertion of a line in a child will usually be done under anesthetic, and general anesthesia poses its own small risk.

Central line catheters are direct pathways into the bloodstream and therefore pose a risk of infection. These include local skin infections, and more serious bloodstream infections that can lead to bacteremia and sepsis.

Thrombophlebitis or clotting of the superficial vein can also occur around a line. A rare, but more serious complication may occur if the tip of the line migrates out of the blood vessel into a surrounding structure. If line infection or breakage does occur the line may need to be replaced. This would expose the patient to the risk of anesthetic and line insertion a second time.

Non-catheter-related complications

Hepatobiliary disease, including cholestasis, is a common and potentially serious complication of PN. Cholestasis is a hepatobiliary complication that is characterized by elevated conjugated bilirubin and presence of stones or sludge on ultrasound of the gallbladder. Premature babies on PN and patients on long-term PN are at higher risk of cholestasis. In pediatric patients with intestinal failure on parenteral nutrition, cholestasis used to be a major source of morbidity and mortality, as well as an indication for liver transplant. Due to alternate lipid emulsions and more consistent care and monitoring, severe cholestatic liver disease is seen less frequently today, however it remains an important concern.

Disturbances in electrolytes and fluids is another possible complication of parenteral nutrition that should be monitored. One cause of electrolyte disturbances is refeeding syndrome, which you should look out for if the child was previously malnourished. For more on refeeding syndrome, check out our episode on Tube Feeding! While not specifically a complication of PN, children with vomiting or diarrhea can have electrolyte abnormalities such as hypokalemia. These will need to be managed along with standard electrolyte requirements in their parenteral nutrition.

While on parenteral nutrition, it is also important to monitor volume status as dehydration and fluid overload can occur because of inappropriate parenteral nutrition administration. Lipid-related complications such as hypertriglyceridemia, hypercholesterolemia, essential fatty acid deficiency, fat overload, can occur because of parenteral nutrition. Excess protein administration results in elevations in ammonia or urea. Hypo- and hyperglycemia can also occur if the glucose solution is not titrated appropriately. These metabolic disturbances need to be monitored for, and the parenteral nutrition prescription may need to be altered if there are abnormalities.

Monitoring during PN

Monitoring during PN should be based on the patient's clinical context. Generally, short term monitoring should include daily weights, baseline labs including a CBC, electrolytes including calcium, magnesium, and phosphorus; triglycerides, cholesterol, total protein, albumin, BUN, creatinine, ALT, GGT, Bilirubin (total and conjugated), and iron studies.

During parenteral nutrition administration, electrolytes, BUN, creatinine, and triglycerides should be monitored daily until deemed stable on a consistent prescription, before reducing to less frequent intervals. As liver disease is an important and serious complication, liver transaminases and bilirubin should be monitored frequently as well on PN, generally on a weekly basis. Albumin and prealbumin should also be monitored as an indication of nutritional status.

For patients on long term PN, further monitoring includes growth monitoring with weight, length, and head circumference. Iron studies and vitamin levels should be checked in the long-term. Abdominal ultrasound, bone mineral density, and renal clearance may also be required, depending on the duration of PN.

Writing orders for parenteral nutrition

Parenteral nutrition recipes are complex. It is valuable to have at least a basic understanding of how to write orders for PN aside from just asking the dietician to do it! The first step in prescribing parenteral nutrition is determining the total energy requirements for the infant or child. For more on calculating energy expenditure and caloric needs, take a listen to the PedCases podcast on tube feeding.

The parenteral nutrition recipe should meet the total energy expenditure in kilocalories. In terms of the PN components, fat requirement in g/kg of the child's body weight should ideally be less than 40% of total kilocalories. Protein requirement is calculated in g/kg, from 3.5 g/kg/day in premature infants down to 1.5 g/kg/day in adolescents. Extra dextrose is then added to meet total calorie requirement. When adding extra dextrose, ensure that the amount of dextrose does not exceed maximum glucose infusion rate. You will also need to calculate the total fluid intake in mL per day and try to keep the total volume of fluid within that amount.

To administer the parenteral nutrition, the ingredients are combined into two bags: one for fats and one for everything else. This should provide all of the nutrients and fluids without exceeding recommended maximums. If you are ordering additional fluids, you will need to carefully consider total fluid infusion volumes as well as content of the fluids. If you are interested in practicing, you can check out the show notes for this podcast, where there is an example of how you might calculate a recipe for Emma.

Case resolution

Let's go back to the case.

Remember, Emma is a 3-year-old girl admitted to the pediatric oncology service for treatment of Non-Hodgkin Lymphoma. She develops severe nausea and vomiting because of her chemotherapy and cannot tolerate tube feeds, which means that she needs parenteral nutrition. She will need nutrition support for a minimum of one week. As Emma is receiving chemotherapy, she already has an implanted venous access device, a type of central line, in place. This will work well for delivering parenteral nutrition.

You calculate a recipe for parenteral nutrition. You also order monitoring blood work for while Emma is on parenteral nutrition. To make a mental note to keep an eye out for some of the possible complications of parenteral nutrition, such as line infections, cholestasis, and hyperglycemia.

Emma's nausea and vomiting recovers over the course of a week following the completion of her chemotherapy cycle. On day 7 of her parenteral nutrition, she is able to take small amounts of fluids by mouth without vomiting. Her NG feeds are restarted and advanced slowly. She is able to go back to full feeds and thus the parenteral nutrition can be discontinued.

Conclusion

Developed by Sierra Casey and Dr. Jason Silverman for PedsCases.com.
June 1, 2021.

That concludes this podcast on parenteral nutrition in pediatrics. In summary:

- Parenteral nutrition is a type of nutrition support that is delivered directly into the bloodstream. It is indicated in infants and children who cannot be fed through the gut for at least three to five days.
- The components of parenteral nutrition are protein in the form of amino acid solutions, fats in the form of lipid emulsions, carbohydrates in the form of dextrose, fluids, and vitamins and minerals.
- Parenteral nutrition can be administered through a peripheral IV, a peripherally inserted central catheter, or a central line.
- Liver disease is a major complication of parenteral nutrition, especially if it is used long term. Catheter-related complications, mainly infection and catheter blockage or breakage are also possible and may result in further procedures for the patient. Electrolyte and metabolic disturbances may also occur therefore patients require specific monitoring while on PN.

References

1. Duggan C, Watkins JB, Koletzko B, Walker WA. Nutrition in Pediatrics: Basic Science, Clinical Applications, Volume 1. 2016.
2. Government of Canada. Dietary Reference Intakes Tables - Canada.ca [Internet]. [updated 2006]. Available from: https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables.html#eeer
3. McGrath KH. Parenteral nutrition use in children with cancer. Pediatr Blood Cancer. 2019 Dec 18;66(12).
4. Lauriti G, Zani A, Aufieri R, Cananzi M, Chiesa PL, Eaton S, Pierro A. Incidence, prevention, and treatment of parenteral nutrition-associated cholestasis and intestinal failure-associated liver disease in infants and children: a systematic review. JPEN J Parenter Enteral Nutr. 2014 Jan;38(1):70-85. doi: 10.1177/0148607113496280. Epub 2013 Jul 26. PMID: 23894170.

Supplemental: Writing Parenteral Nutrition Orders

Emma is a 15 kg, 100 cm tall 3-year-old girl who will need parenteral nutrition for about a week while she completes her chemotherapy cycle.

Ingredients: ● Energy: ____ kcal (based on the REE) ● Protein: ____g/kg (2 g/kg) ● Fat: ____ g/kg (<2 g/kg, ~40% of total calories) ● Dextrose: max GIR = 6 mg/kg/min ● Water: TFI = ____ mL/day ● Vitamins, electrolyte, minerals For our patient: ● Energy: ~970 kcal/day ● Protein: ~ 30 g/day = 120 kcal ● Fat: < 30 g/day = 270 kcal ● Dextrose: max GIR = 6 mg/kg/min ○ 710 kcal/day remains ○ Dextrose has 4 kcal/g ○ 177.5 g/day dextrose ● Water: minimum TFI = 1200 mL/day ● Vitamins, electrolyte, minerals	Directions: ● Combine ingredients in 2 bags, 1 for fat, 1 for everything else. ● Provide all nutrient and fluid requirements without exceeding maximums ● Can exceed minimum fluid requirement but stay within reasonable limits Calculations: ● Calculate TFI (minimum fluid requirements) based on 4-2-1 formula ● Calculate lipid amount and deduct from total calories (ideally <40% of kcal).

To calculate a parenteral nutrition recipe:

1. Calculate resting energy expenditure and fluid requirements

Emma weighs 15 kg and is 100 cm tall, so you estimate her resting energy expenditure to be around 970 kilocalories per day, using the Harris Bennedict Equation. Using the 4-2-1 formula, her minimum hourly fluid requirement should be 50 mL per hour, or 1200 mL/day.

2. Calculate macronutrient solutions

<u>Fat:</u>

- *Fat should make up less than 40% of total calories, and less than 2 g/kg/day.*
- *Fats are given as 20% lipid emulsion, which provides 2 kcal/mL and 0.2 g of fat per mL.*
- *15 kg x 2g/kg/day = 30 g/day, maximum. This is 1.25 g/hr, or 6.25 mL/hr.*

- *Lipid emulsions are typically run separately, so you decide to run the 20% lipid emulsion at 6 mL/hr.*

<u>Protein:</u> Children need 2 g/kg/day of protein, therefore we should make sure Emma is getting at least 30 g per day. Using a 2.5% amino acid solution this means running the solution at at least 50 mL/hr.

<u>Glucose:</u> The rest of the calories can come from glucose. 580 calories remain out of her 970 calorie resting energy expenditure. Ideally she would get 170 g of dextrose throughout the day, as dextrose provides 3.4 kcal/g. However, this amount is limited by the maximal glucose infusion rate, which in children is a maximum of 6 mg/kg/min. The maximal infusion rate is 90 mg/min or 5.4 g/hr, which is equivalent to a 10% solution running at 54 mL/hr, for 129 g/day total. We can run the glucose and protein solutions together so they will both have a rate of 54 mL/hr.

3. Add up the components and calculate TFI

Putting the whole recipe together, you get 2.5% amino acids + 10% dextrose running at 50 mL/hr and 20% lipid emulsion running at 6 mL/hr. This means that her total fluids are 56 mL/hr, which works out to 1344 mL/day. This is above our estimated fluid requirement, but remains within reasonable limits. Kcal are below the allotted amount, which would need to be addressed if she was on longer-term PN.

Final recipe

- Energy: 856 kcal/day
- Protein: 2.5% AA solution at 54 mL/hr = 32.4 g/day = 130 kcal
- Fat: 2 g/kg/day = 30 g/day = 288 kcal
- Dextrose: 129 g/day = 438 kcal
    - GIR = 6 mg/kg/min
- Water: 1440 mL/day
- Vitamins, electrolyte, minerals