Partial Parenteral Nutrition in Equine Neonatal Clostridial Enterocolitis*

K. Tillotson, DVM, MS
J. L. Traub-Dargatz, DVM, MS, DACVIM
P. K. Morgan, RPh
Colorado State University

ABSTRACT: Partial parenteral nutrition (PPN) is a key component in the management of equine neonatal clostridial enterocolitis. These foals are often unable to ingest anything orally and are in a negative energy balance. The recipe provides 1 kcal/ml and is administered at 1 mg/kg when delivering 33% of the chosen total energy requirements for a sick neonatal foal. Although the nutritional requirements of sick neonatal foals are unclear, we have devised a neonatal PPN recipe and plan of administration that is user-friendly and cost-effective.

The clinical management of ill equine neonates continues to improve each year. Although many clinicians consider the use of parenteral nutrition daunting, we have found it to be cost-effective, clinically useful, and relatively easy to administer.

We use partial parenteral nutrition (PPN) in our clinic as a key component in the management of equine neonatal clostridial enterocolitis, a disease that results in serious illness. Diarrhea—that is sometimes bloody—and colic are common clinical signs of Clostridium perfringens or Clostridium difficile.1–4 Both of these organisms can cause acute gastrointestinal disease in young foals. Foals most commonly become ill at 2 to 4 days of age and have a history of being vigorous at birth with adequate passive transfer.5 Often the affected foal will suckle the mare, then drop to the ground and roll on its back. The presence of colic signs or bloody diarrhea indicates a need for prompt medical attention. Foals affected by this disease often require intensive medical care. Dietary restriction, IV fluid support, correction of electrolyte imbalances, parenteral and enteral antibiotics, gastric ulcer prophylaxis, pain management, and good nursing care are basic elements of the treatment plan.1,4

Although the specific nutritional requirements of equine neonates are unclear, a neonatal foal unable to suckle its mare requires alternative nutritional support. The use of isotonic polyionic fluids supplemented with dextrose provides inadequate nutritional support for prolonged periods (i.e., >24 hours). If the foal can tolerate enteral nutrition, mare's milk is the preferred method of nutritional support.6 Mare's milk provides essential nutrients and aids in intestinal health by providing energy to enterocytes and colonocytes.6,7 Intestinal health plays an important role in the prevention of translocation of bacteria and endotoxins across the intestinal wall.6 PPN is often avoided because of the perceived difficulty of administration, expense, and inferiority to enteral nutrition for maintenance of intestinal health.7

Foals with clostridial enterocolitis have moderate to severe abdominal pain that ranges from intermittent to continuous. Enteral feeding may be contraindicated for up to 5 days due to abdominal pain, distention, and ileus. We speculate that milk provides clostridial organisms with excellent growth media for replication and production of gas and toxins, which contribute to abdominal pain.

*The prices reflected in this article are based on cost information gathered in September 2002.
†Dr. Tillotson is currently affiliated with Tillotson Equine Internal Medicine Mobile Services, Leesburg, North Carolina.
Rationale for the Composition of the PPN Solution

The solution is composed of dextrose (Dextrose 50%, Vedco), lipids (Liposyn II 20%, Abbott Laboratories), amino acids (Aminosyn II 10%, Abbott Laboratories), and B-complex vitamins. Dextrose is the cheapest component, yet it offers the lowest caloric density (3.4 kcal/g). If one were to provide all of the needed calories with dextrose alone, an extremely hyperosmolar solution would have to be administered. Use of such high levels of dextrose can lead to phlebitis and glucose intolerance. Yet glucose cannot be completely replaced with a more calorically dense material (e.g., lipids) because the body requires glucose for oxidation of fatty acids and because glucose is superior to lipids in its nitrogen-sparing effect. There are several benefits to the addition of lipids. A 20% fat emulsion is more calorically dense than dextrose or amino acids (9.0 kcal/g) and is isotonic. Amino acid solutions are relatively low in caloric density (4 kcal/g), but these are needed as building blocks for the creation of endogenous proteins rather than for production of energy. Although the body requires other micronutrients and trace minerals, the short duration of treatment precludes cost-effective use of multivitamin and mineral supplements. Alternatively, B-complex vitamins are provided at 1 ml/L in PPN solution.

Formula Options

Although prices may vary, some current average wholesale prices are provided. Dextrose 50% is commonly available in 500-ml bottles at a cost of $2.50 each. Liposyn II 20% is available in 500-ml bottles for $30 each. Aminosyn II 10% is most recently available in 2,000-ml bags at a cost of $35 each. A batch of PPN solution is made of 1 L dextrose 50%, 0.5 L Liposyn II 20%, 2 L Aminosyn II 10%, and 3.5-ml B-complex vitamins. The total PPN solution cost to the clinic is approximately $70. The total batch volume is approximately 3.5 L. A single batch is adequate for treatment of an average-sized foal for 1.5 to 3 days, depending on the rate of administration (Table 1).

Some formulas do not include any caloric contribution from the amino acid solution in an attempt to maximize the amount of amino acids provided for protein synthesis rather than energy expenditure. However, in the above formula, inclusion of amino acids makes for a more user-friendly conversion (1 kcal/ml). We developed this formula with ease of administration and optimization of shelf life of materials in mind.

Compounding the PPN Solution

Compounding the PPN solution must be performed with strict aseptic technique. Most veterinary pharmacies have a laminar flow hood. If one is not available, local human hospital pharmacies or home health care facilities may offer to mix the solution. However, if one is careful, mixing under a laminar flow hood is not absolutely necessary. The order of mixing is, however, critical. Dextrose and amino acids are mixed first, and then lipids are added last to minimize lipid demulsification. Sterile fluid bags with lead transfer sets (McGaw, Inc.) can be purchased, but 3-L sterile saline fluid bags using primary sets minimize cost and are convenient. A batch is typically split in half (1,750 ml) and placed into two separate 3-L sterile bags. The first bag is used immediately and the second is typically kept refrigerated for up to 36 hours until needed. Although it has been suggested that PPN solutions should not be refrigerated longer than 15 hours, we have not experienced problems after 36 hours of refrigeration. This may be due to the extreme precautions that we take to maintain sterility. A series of bacterial cultures on a test batch of refrigerated solution is suggested.

Calculation of Energy Requirements

The goal of this update is to demonstrate the ease of PPN use in equine neonates with gastrointestinal disease. We would be remiss not to

Table 1. Ingredients for Making a Batch of PPN Solution

<table>
<thead>
<tr>
<th>Solution</th>
<th>ml/Batch</th>
<th>kcal</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dextrose 50%</td>
<td>1,000</td>
<td>1,700</td>
<td>$5</td>
</tr>
<tr>
<td>Lipids 20%</td>
<td>500</td>
<td>900</td>
<td>$30</td>
</tr>
<tr>
<td>Amino acids 10%</td>
<td>2,000</td>
<td>800</td>
<td>$35</td>
</tr>
<tr>
<td><strong>Total batch</strong></td>
<td>3,500</td>
<td>3,400</td>
<td>$70</td>
</tr>
</tbody>
</table>

*aCost/day is based on wholesale prices because percentage mark-up may vary.*
include some background on calculation of energy requirements. There are many formulas for calculating energy requirements of patients, but none is available specifically for neonatal foals. Individual factors to consider include the foal’s maturity, size, and breed as well as the type of disease. There are no published studies on the nutritional requirements of sick neonatal foals. Some conservative formulas are based on modifications of interspecies equations for resting energy requirements (RERs): 

\[
\text{RER (kcal/day)} = 70 \times \left( \frac{\text{Body weight [kg]}}{4} \right)^{0.75}
\]

Total daily energy requirements (TERs) are calculated by multiplying RER by factors ranging from 1.2 to 2. For example, by multiplying the RER by a factor of 1.35, the TER for a 50-kg foal is approximately 1,000 kcal/day or 20 kcal/kg/day. It has been suggested that providing 50 to 70 kcal/kg/day may maintain weight in a sick neonate. When we first began implementing PPN in our neonatal equine patients, we were conservative in our energy calculations; however, over the past 3 years, we have found that using 70 kcal/kg/day as the TER clinically appeared to be the most appropriate. When comparing our formula and plan with others, it is important to keep in mind that we are including a caloric contribution from protein when we define the solution as having 1 kcal/ml.

**Deciding on the Rate**

PPN solutions are not physiologic, and tolerance can be a potential problem. One of the most cited concerns is that the solutions may result in hyperglycemia or hyperlipidemia.\(^7\) PPN solutions are often started at a predetermined percent of TER, such as 25% to 33%, and then increased by 25% to 33% as needed. We rarely find it necessary to provide 100% of the foal’s calculated requirements, and most foals maintain their blood glucose levels and do not become hyperlipidemic. Foals with clostridial enterocolitis that are given PPN do not receive any food by mouth for 3 to 5 days, yet they typically maintain their weight and begin gaining weight within 1 to 2 days of transitioning to enteral feeding.

It is important to remember that the formula provides 1 kcal/ml. Based on 70 kcal/kg/day and starting at 33% of TER, a 50-kg foal would initially be given 50 ml/hr. Therefore, our rule of thumb is hourly rate equals kg/hr at 33% of TER. After 12 hours, we increase the rate to 66% of TER; thus the hourly rate equals 2 kg/hr at 66% of TER. In most cases, we continue at this rate for 48 hours and then begin to wean the foal off the PPN solution by decreasing the rate back to 33% for another 12 hours. We have found this plan to be well tolerated by foals with clostridial enterocolitis. Mark-up from wholesale prices may vary; however, in our clinic, this plan results in a total PPN solution cost of $150/batch of 3,500 ml or about $50/day (Table 2).

<table>
<thead>
<tr>
<th>% TER</th>
<th>Rate</th>
<th>ml/hr</th>
<th>PPN Cost/Day*</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>1 ml/kg/hr</td>
<td>50</td>
<td>$24</td>
</tr>
<tr>
<td>66</td>
<td>2 ml/kg/hr</td>
<td>100</td>
<td>$48</td>
</tr>
<tr>
<td>100</td>
<td>3 ml/kg/hr</td>
<td>150</td>
<td>$72</td>
</tr>
</tbody>
</table>

*Cost/day is based on wholesale prices because percentage mark-up may vary.

Although we are not meeting the complete energy needs of these neonatal foals, they are provided with enough nutritional support to avoid energy depletion during a phase of the disease in which enteral nutrition is not an option. Many of these foals are also managed with colloid fluids as needed to maintain serum protein levels and hydration. It is our clinical impression that case mortality and hospitalization times have decreased since the institution of gastrointestinal rest and use of PPN in the management of foals with clostridial enterocolitis.

**Administration and Required Equipment**

An IV bolus of PPN solution increases the risk of metabolic complications and, therefore, is not recommended.\(^6\) The use of programmable infusion pumps is safe and easy. Sterility is key in the prevention of sepsis associated with PPN as these solutions are ideal media for bacterial growth. Catheters should be placed using methods to optimize sterility and minimize trauma to the vein. Clean gloves should be worn by all personnel when handling IV lines. All IV lines and catheter bandages should be replaced every 24 to 36 hours. Catheters that reduce the risk of venous thrombosis should be used, and catheter sites must be monitored closely.\(^6\) Foals with severe protein-losing enteropathy are at increased risk for thrombophlebitis due to loss of antithrombin III, and PPN solutions are hyperosmolar and irritating to the veins. Although phlebitis is not an indication for termination of therapy, at any sign of pain, heat, or swelling the catheter should be removed and relocated.\(^6\)

Ideally, the line used to deliver the PPN solution should be a dedicated line that is not handled for other reasons (e.g., drug administration, blood sampling). This line should not be disconnected except to replace tubing for PPN bags. In many patients, a catheter is placed before

---

**Table 2. Summary of the PPN Plan for a 50-kg Foal**

- **% TER**: Percentage of Total Energy Requirements
- **Rate**: Rate of Administration
- **ml/hr**: Milliliters per Hour
- **PPN Cost/Day**: Cost per Day (Based on Wholesale Prices)

---

**Notes**

- RER by a factor of 1.35 results in a total PPN solution cost of $150/batch of 3,500 ml or about $50/day.
- Catheters that reduce the risk of venous thrombosis should be used.
- Phlebitis is not an indication for termination of therapy, at any sign of pain, heat, or swelling the catheter should be removed and relocated.
- PPN solutions are hyperosmolar and irritating to the veins.
- PPN solutions should be a dedicated line.
- Catheters should be replaced every 24 to 36 hours.
- Sterility is key in the prevention of sepsis associated with PPN as these solutions are ideal media for bacterial growth.
the decision to use PPN solution is made and placement of a second catheter is avoided due to the increased risk of venous thrombosis in foals with protein-losing enteropathy. We have had good success using a single catheter for all IV treatments, including PPN. The PPN line is connected to the IV port of the primary fluid line, covered with antiseptic ointment, and handled infrequently. This allows the catheter lumen that is receiving the PPN to be flushed regularly with antibiotics. When handling the primary line, we first turn the PPN pump off to allow flushing of the primary line with crystalloid fluids and to minimize contact with the PPN solution.

During administration, we cover the bags of PPN solution with the black plastic bag that comes as part of the packaging of the amino acid solution to avoid light damage such as increased oxidation of lipids, amino acid breakdown, or B-vitamin breakdown. We are not sure if light exposure poses a major risk to PPN solutions, but covering the bags is an easy precaution to perform.

Foals with clostridial enterocolitis are usually dehydrated, electrolyte and protein depleted, and in varying degrees of hypovolemic shock. Initial stabilization with crystalloid and colloid fluids is the mainstay of initial treatment in these foals. After stabilization, PPN treatment can begin with a fixed rate of 33% (TER) or 1 ml/kg/hr. Crystalloid fluids are then supplemented with electrolytes and dextrose as needed. Most foals tolerate 2.5% dextrose along with the dextrose in the PPN solution.

Complications and Monitoring

We have observed very few complications using the plan described above for PPN administration, probably because most foals are treated with PPN for only 72 hours. Potential complications can be mechanical, metabolic, or septic. Mechanical problems are the most common and include line occlusion, breakage or contamination, and thrombophlebitis. Metabolic derangements are uncommon. We typically monitor blood glucose levels every 4 to 6 hours and triglyceride levels daily. In general, using the formulas and rates described earlier, foals with clostridial enterocolitis tolerate PPN therapy well. Close monitoring allows adjustments if necessary. If serial blood glucose levels fall below 80 mg/dl or exceed 200 mg/dl, we typically adjust the percent of dextrose and the rate of administration of crystalloid fluid treatment or both rather than changing the PPN formula. If hyperlipidemia occurs (e.g., triglyceride levels >200 mg/dl), the PPN formula is readjusted by decreasing the percent of dextrose and the rate of administration of crystalloid fluid treatment because the rate of PPN administration is low and fixed. Sepsis is the most serious complication, but this problem can be minimized by strict adherence to aseptic technique in catheter placement and handling of IV lines.

Cost-Effectiveness

Most foals requiring the use of PPN solutions are critically ill and need intensive medical care. By following the described procedures, use of PPN does not significantly increase the labor or material cost. The use of two batches (7 L) of PPN solution is more than adequate to support a foal through the initial phases of clostridial enterocolitis. When treating the typical 50-kg foal at 50 ml/hr for 12 hours then 100 ml/hr for 48 hours and 50 ml/hr for an additional 12 hours, a total of 6 L of PPN solution is used. In some cases, the foal responds more quickly, and a single batch may be all that is required.

Protocol

A typical scenario for equine neonatal clostridial enterocolitis is a 3-day-old foal with bloody diarrhea or colic or both. These foals are often dehydrated, hypoglycemic, electrolyte depleted, acidic, and neutropenic. Resuscitative treatment, including the use of crystalloid and colloid IV fluids, is initiated, and PPN is typically started after 6 to 12 hours of hospitalization. Initially, oral intake is completely restricted. The foals are supported with gastric ulcer protectants, parenteral antibiotics with or without oral antibiotics (depending on the degree of ileus), IV crystalloid and colloid fluid treatment, and PPN.

Often after 36 to 48 hours of treatment, the foal is able to tolerate enteral fluids. Oral electrolyte solutions, such as Biolyte (PBS Animal Health), are offered first. It is our clinical impression that milk provides an excellent medium for clostridial growth and toxin production; thus milk is restricted until the foal has demonstrated the ability to tolerate electrolyte solutions. Initially, 50 to 100 ml of oral electrolyte solution is offered hourly, which is 2.5% to 5% of the foal’s body weight divided over a 24-hour period. If this is tolerated for 6 to 12 hours, then oral electrolyte solution is replaced with milk or milk-replacement solutions. We do not offer oral electrolyte solutions containing bicarbonate and milk within the same hour due to a perceived risk of inhibiting milk curd formation. Most often, the process of returning the foal to enteral feeding is well tolerated. Occasionally, despite gradual reintroduction, the foal exhibits signs of abdominal pain following oral intake of either electrolyte solution or milk. In these foals, oral intake is again restricted, and PPN is contin-
ued for another 24 hours. Most commonly, foals tolerate oral electrolyte solutions but not milk. In these foals, PPN treatment is continued, IV crystalloid fluid treatment is adjusted according to the oral electrolyte solution intake, and milk is withheld for another 24 hours.

Summary

Many management factors play a role in whether treatment of foals with clostridial enterocolitis is successful. Foals with severe hypoproteinemia are also managed with IV plasma and other colloid fluids, which most certainly have an impact on treatment success. Many foals with clostridial enterocolitis require treatment with PPN, and we feel that they tolerate it well. It is our clinical impression that mortality and length of hospitalization have decreased with the institution of this treatment early in the course of this disease. We have made every attempt to simplify the use of PPN treatment to enable its use for equine neonatal patients within cost and personnel restraints.

References