Nutritional Support of the Neonate

Jon Palmer, VMD, New Bolton Center, University of Pennsylvania

The transition from fetal to neonatal life results in the removal of a constant supply of a number of nutrients including glucose, calcium, magnesium, and fluids. The maternal physiology and normal placenta have supplied all of these constituents. Suddenly without the constant supply of these nutrients, the fetus must make the transition to supplying and regulating these vital substances itself. During this transition period, the fetus may become transiently hypoglycemic (trough at 2 to 4 hours old) or hypocalcemic. This hypoglycemia is important in stimulating search and suckle behavior and glycogenic response. Likewise, the initial drop in blood calcium levels probably are important in stimulating normal calcium regulating responses. Both of these normal nutrient patterns should not be treated, but followed closely since in the abnormal neonate, regulatory mechanisms may be slow to develop and support may be needed. Nutritional support during the early neonatal period consists of intravenous fluids with dextrose and balanced electrolytes (directed by lab findings) until it can be established whether enteral or parenteral route will be use for nutrition.

Some neonates become hyperglycemic during this early period. This response may be secondary to decreased serum glucose clearance, diminished response to insulin, or increased cortisol levels mediated by stress. Conversely some neonates are susceptible to hypoglycemia due to limited hepatic glycogen stores and inadequate endogenous glucose production. Neonates who have experienced perinatal asphyxia, intrauterine growth retardation (placental insufficiency) or cold stress are at high risk for developing hypoglycemia.

Enteral feeding is preferred over parenteral feeding. Advantages of enteral feeding include physiologic stimulation leading to normal metabolic regulation, preservation of gastrointestinal mucosa integrity, important trophic substances (including epidermal growth factor and insulin-like growth factors) which stimulate normal growth and development and lower cost. A significant number of critically ill neonates have enough gastrointestinal dysfunction that parenteral feeding is required for at least part of their nutritional support. Minimum requirements for initiating enteral feeding include the absence of abdominal distension, the absence of gastric reflux, passage of meconium and presence of active bowel sounds. Great care needs to be taken with neonates that have had any indication of perinatal asphyxia or hypoxia. Stable blood pressure, temperatures near 100F, normal P_{aO_2} and stable blood glucose levels are also important parameters indicating that enteral feeding may be safe. When in doubt, small enteral feeds should be given. In no case should large volume enteral feeding be initiated until the health of the GIt is assured.

Fresh mother's milk is the preferred source of enteral nutrition for the neonates because of its unique nutrient composition, increased bioavailability of nutrients, immunologic properties, promotion of maternal-neonate bonding, and present of hormones, enzymes, and growth factors. When fresh mother's milk is not available, frozen milk from the same species is the next best product followed by high quality powdered milk replacer specially formulated for that species to match the natural mother's milk. Each species' milk is unique and quite different from other species. Only milk replacer made by manufacturers who pay close attention to their formulations should be used. There are specific milk replacers made for several hundred different mammalian species. Different species have different density milk and require different volumes based on that. For the remainder of this discussion I will be considering nutritional therapy primarily in foals and other herbivores. The amounts suggested may not be appropriate for other species depending on their milk composition. Occasionally other species milk may be used successfully in raising neonates, but this is far from ideal. A case in point is the use of goat's milk in raising foals.

If enteral feeding appears to be a safe route, initially the foal should be fed 5% of his weight per 24 hours divided into 12 feedings. If the foal appears to tolerate this volume, the amount can be increased to reach a goal of 10% during the second day and further increased to a target. Although normal foals may consume 20-25% of their weight per day, they expend much energy exercising. Stall confined sick foals seem to do better with intakes of 12-14%. The intake should be guided by a weight gain goal of 1-2 lb per day. If enteral feeding is questionable, trial feedings of 4-6 ounces every 4-6 hours may be appropriate. In any case, care must be taken to provide enough calories and protein using the parenteral route to make up the difference between what can be given by the enteral route and what is required.

Physiologically the best method for enteral feeding is by normal suckling. Unfortunately in the critical foal this is rarely possible. Many foals with NE (neonatal encephalopathy) have abnormal suckling behavior. They may seem to desperately want to suck and try very hard, but they are ineffective. These foals are at high risk for aspiration because of the uncoordinated suckle. Unfortunately the naive caregiver will see the enthusiastic suckle as hopeful and may persist in attempting to get the foal to drink resulting in aspiration of a significant volume. Aspiration in a healthy neonate has few consequences as long as the volume is not large. However in the critical neonate with asphyxia/hypoxic damage and the neonate who spends most of his time recumbent, aspiration may result in significant pulmonary disease, which may in turn become a fatal sequela. Aspiration must be avoided at all costs. If the foal cannot suckle effectively then he should be fed via nasogastric tube. Placement of a small diameter indwelling nasogastric tube is a very good method of feeding. Foals seem to tolerate these tubes much better than an indwelling large diameter tube or having a nasogastric tube passed every two hours. Ideally the foal should be fed at least every two hours. If he is suckling it should be on demand and frequent. If he's being fed through an indwelling nasogastric tube, bolus feeding every 2 hours appears to be a safe approach.

Parenteral Nutrition

Protein Requirements: Traditionally protein requirements are estimated based on studies of amino acid utilization of the late term fetus. These studies assume that normal growth will occur if parenteral nutrition meets the same protein and energy delivery as the placenta. Most estimates (based primarily on studies in lambs) suggest that parenteral nutrition will replicate intrauterine rate of nitrogen delivering with 2.7 to 3.5 gm per kg per day of amino acids when total energy is greater than 70 kcal per kg per day. Stress, infection, SIRS, other catabolic demands may increase the amount needed to meet growth requirements.

Glucose requirements: Glucose is the primary source of energy in the developing fetus. By term gestation, the net umbilical uptake is 4 to 7 mg per kg per minute of glucose, which is 6 to 10 gm of glucose per kg per day. This level does not provide all the calories required to meet the total needs of the developing fetus. In fact, 80% of fetal glucose uptake can be accounted for by brain and muscle metabolism. Glucose is also stored as glycogen, predominantly in the liver, skeletal muscle, and cardiac muscle. Fetal insulin and the fetal pituitary-hypothalamic-adrenal axis regulate fetal liver glycogen synthesis. There is net glycogen accumulation in the fetal liver with active turnover. The fetus is unable to carry out gluconeogensis, because of either low activity or absence of phosphoenolpyruvate carboxykinase (at least in the sheep fetus). The fetus also lacks glucose-6-phospatase until just before birth unless stimulated by poor maternal nutrition. Only states of severe maternal fasting (> 7 days in the sheep) will induce fetal glucose production.

At birth, glucose is released (after production of glucose-6-phospatase) through hepatic glycogenolysis and stimulation of gluconeogenesis, via catecholamine secretions that rise after birth. Umbilical cord rupture leads to an increase in glucagon, facilitating glucose mobilization. At birth the stimulated fetal liver produces 4 to 8 mg of glucose per kg per minute. When hypoglycemia occurs, delivering this same rate via intravenous fluids is appropriate. If the damn has been hyperglycemic before parturition, the fetus may be hyperinsulinemic and these individuals may require higher glucose infusion rates.

Lipid requirements: Although lipids are not utilized in the fetus as an energy source under normal circumstances, in periods of stress they may become very important. Unlike in human premature neonates, much of the neuronal development is near completion in the foal and there is no critical need for lipids in completing this process. However neonatal foals utilize lipids readily as an energy source when it is provided. Lipid particles are carried in the circulation as triglyceride-fatty acids within chylomicrons or very low density lipoproteins. In order for the free fatty acids to be utilized, lipoprotein lipase catalyzes removal of the triglyceride-fatty acid component from within the particle. Lipoprotein lipase is present within the endothelial wall to varying amounts in body tissues. It has been demonstrated that concurrent heparin administration during parenteral nutrition facilitates release of lipoprotein lipase and thus increases clearance of lipid emulsions. Lipoprotein lipase determines the pattern of uptake of exogenous lipids from the blood stream because of its rate limiting step in absorption and its concentration varies according to tissue demands. Heparin in amounts as little us 1 unit per hour in human neonates provides sufficient stimulus for increased lipid protein lipase activity. Generally 40 to 50% of the total caloric intake can come from fat. One potential complication of lipid infusion is that common binding sites on the albumin molecule may result in competitive release of bilirubin if excessive amounts of lipids are infused. Thus this therapy should be used with extreme care in hyperbilirubinemic neonates. Another possible side effect from lipid emulsions is interference with oxygenation. P_{ao_2} has been shown to fall when lipid therapy is initiated. This appears to occur more commonly at lower doses and when bolus infusion is utilize. At present it is commonly accepted that lipids should be infused over a 24-hour period or a prolonged period with a few hours with no infusion. This also results in more stability in blood triglyceride levels and lipoprotein lipase levels. There is some debate about the effects of lipids on platelet function. There have been both reports of decreased platelet function and improved coagulation function went lipids are administered.

Numbers/formulas used in nutritional support of foals:

Intravenous fluids for neonates - one method for calculating fluid requirements:

For each Kg up to 10 kg - 100 ml/kg/ 24 hours

For each Kg from 11-20 kg - 50 ml/kg/ 24 hours

For each Kg > 20 kg - 25 ml/kg/ 24 hours

Example: 50 kg foal

> 1000 ml for 1st 10 kg body wt
> + 500 ml for 2nd 10 kg body wt
> + 750 ml for 30 kg more wt
> total = 2250 ml/day or 94 ml/hr

***Dextrose rate for neonates*:** 4-8 mg/kg/min

Example: 50 kg foal given 6 mg/kg/min

Amount glucose needed/hr = 50Kg X 6 mg/kg/min X 60 min. = 18,000 mg

Amount of 10% dextrose solution needed = 18,000 mg / 100 mg/ml = 180 ml/hr

Enteral Feeding Requirements

Example 20% of body weight - 114 kcal/kg/day

110 lb Foal

110 lb X 20% = 22 lb

22 lb X 16 oz/lb = 352 oz/day

352 oz / 12 feedings = 29 oz/feeding

50 kg Foal

50 kg X 20% = 10 kg = 10 liters

10 liters / 12 feedings = 833 ml/feeding

Parenteral Nutrition Formula

Example - 50 kg foal
Dextrose - 10 gm/kg/day - 34 kcal/kg
Amino acids - 2 gm/kg/day - 8 kcal/kg
Lipids - 1 gm/kg/day - 11 kcal/kg
Plus vitamins and trace minerals
Total - 53 kcal/kg
Nonprotein kcal - 24% lipid
Nonprotein kcal per gram nitrogen = 139.5

Foal Nutrition - Numbers to know

Glucose - 3.4 kcal/gm

Amino acids - 4.0 kcal/gm

Lipid - 9.0 kcal/gm

6.25 gm amino acids = 1 gm nitrogen

1 oz = 30 ml

16 oz milk = 1 lb

Mare's milk - 0.57 kcal/ml