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Fluid Therapy in the Foal: Neonate Onward

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Take Home Message

Fluid therapy in foals can be undertaken in the field, keeping in mind some differences between the neonate and the adult. The intravenous route should be used for initial resuscitation and administration of glucose and plasma. Oral fluid supplementation is possible, but should only be done under gravity flow.

Because the renal function and vascular physiology of the equine neonate is substantially different from the adult, fluid therapy in the neonate cannot simply be scaled down from adult therapy. Fluid therapy should be conservative during postpartum resuscitation, as the newborn foal is generally not volume depleted unless excessive bleeding has occurred. Some compromised newborn foals are actually hypervolemic. If intravenous fluids are required for resuscitation administration of 20 ml/kg of a non–glucose-containing polyionic isotonic fluid over 20 minutes (about 1 L for a 50-kg foal), known commonly as a ‘shock bolus’, can be effective. Non–glucose-containing polyionic intravenous fluids should be used because hyperglycemia, but not hypoglycemia, immediately after fetal or neonatal asphyxia has been shown to interfere with the recovery of brain cell membrane function and energy metabolism in neonatal piglets. These findings suggest that post–hypoxic-ischemic hyperglycemia is not beneficial and might even be harmful in neonatal hypoxic-ischemic encephalopathy. Indications for this ‘shock bolus’ therapy include poor mentation, poorly palpable peripheral pulses, and the development of cold distal extremities, compatible with hemorrhagic shock. The foal should be reassessed after the initial bolus and additional boluses administered as necessary. These same indications should be used when administering ‘shock bolus’ treatment to neonates with other conditions requiring fluid resuscitation, such as sepsis. Ideally, follow up should include measuring blood pressures and obtaining ECG readings. For the practitioner, failure to respond well to bolus therapy probably indicates a need for referral to a hospital where continuous fluid therapy and, potentially, inopressor therapy, can be more safely and readily administered. If blood loss appears to be significant, referral should also be considered for administration of blood.

Glucose-containing fluids can be administered as a constant rate infusion (CRI) both after resuscitation and for energy support in the sick neonatal foal at a rate of 4 to 8 mg/kg/min, particularly in the obviously compromised foal. A rapid method of calculating an appropriate rate in the field for administering 5% dextrose at 4 mg/kg/min is as follows:
[(Body weight in pounds) x 2] + [(Body weight in pounds) x 10%] = #mls/hour

For a 100 lb foal, this becomes:

\[
[(100) \times 2] + [(100) \times 10\%] = 200 + 20 = 220 \text{ mls 5% dextrose/hour}
\]

If this rate is not sufficient to keep blood glucose concentration within a normal range (60-160 mg/dl) then the rate can be doubled, or the same rate can be used with a greater dextrose concentration, such as 10% dextrose. Hand-held glucometry units are commonly used to monitor glucose concentrations in the blood or plasma, but should be assessed for their accuracy in the specific conditions they are used in, as they can be quite inaccurate.\(^6,7\)

CRI glucose therapy is indicated to help resolve metabolic acidosis, to support cardiac output because myocardial glycogen stores likely have been depleted, and to prevent postasphyxial or sepsis associated hypoglycemia. Under normal conditions, the fetal-to-maternal blood glucose concentration gradient is 50% to 60% in the horse, and glucose is the predominant source of energy during fetal development.\(^8,9\) Glucose transport across the placenta is facilitated by carrier receptors (glucose transporter [GLUT] receptors), and a direct relationship exists between maternal and fetal blood glucose concentration when maternal glucose is in the normal range.\(^8\)

At term, the net umbilical uptake of glucose is 4 to 7 mg/kg/min, with most of the glucose being used by the brain and skeletal muscle.\(^10-13\) The fetus only develops gluconeogenesis under conditions of severe maternal starvation. A certain percentage of the delivered glucose is used to develop large glycogen stores in the fetal liver and cardiac muscle in preparation for birth, and at birth the foal liver produces glucose at a rate of 4 to 8 mg/kg/min by using these stores. Fetal glycogen stores also are built using the substrates lactate, pyruvate, and alanine; fetal uptake of lactate across the placenta is about half that of glucose.\(^8,15\) The transition to gluconeogenesis, stimulated by increased circulating catecholamine concentration from birth and by stimulation of glucagon release at the time the umbilical cord breaks takes 2 to 4 hours in the normal foal, and glycojenolysis supplies needed glucose until feeding and glucose production are accomplished.\(^14\)

In the challenged foal, glycogen stores may have been depleted and gluconeogenesis delayed, so provision of glucose at rates similar to what the liver would normally produce during this period is requisite.

The clinician managing critically ill neonates must recognize that intravenous fluid therapy simply cannot be scaled down from adult management approaches. Fluid management of the ill neonate, particularly over the first few days of life, must take into consideration that the neonate is undergoing a large transition from the fetal to the neonatal state and that important physiologic changes are taking place.\(^15\) These transitions include shifts in renal handling of free water and sodium and increased insensible losses because of evaporation from the body surface area and the respiratory tract. The newborn kidney has a limited ability to excrete excess free water and sodium, and the barrier between the vascular and interstitial space is more porous than that of adults. Water and sodium overload, particularly in the first few days of life, can have disastrous long-term consequences for the neonate.\(^16,17\) In the equine neonate, excess fluid (and sodium) administration frequently manifests as generalized edema formation and excessive weight gain, frequently equivalent to the volume of excess fluid administered intravenously. In cases in which
antidiuretic hormone (ADH) secretion is inappropriate, as in some foals with hypoxic/ischemic events at birth, generalized edema may not form, but the excess free water is maintained in the vascular space. This ‘syndrome of inappropriate anti diuretic hormone secretion’ is recognized in the foal that gains excessive weight not manifested as edema generally, with decreased urine output and electrolyte abnormalities such as hyponatremia and hypochloremia.418 The foal manifests neurologic abnormalities associated with hyponatremia. The serum creatinine concentration varies in these cases, but urine always is concentrated compared with the normally dilute, copious amounts of urine produced by foals more than 24 hours of age on a milk diet. The treatment for this disorder is fluid restriction until weight loss occurs, electrolyte abnormalities normalize, and urine concentration decreases. If the clinician is unaware of this differential diagnosis, the neonate can be assumed mistakenly to be in renal failure, and the condition can be exacerbated by excessive intravenous fluid administration in an attempt to produce diuresis.

The problem of appropriate fluid management in critically ill neonates has been recognized by medical physicians for years and has resulted in changes in fluid management of these patients. The approach taken has been one of fluid restriction, in particular sodium restriction but also free water restriction, and has resulted in improved outcome and fewer complications, such as patent ductus arteriosus and necrotizing enterocolitis.16,17 The calculations used for ‘dry’ maintenance intravenous fluid support in these patients takes into consideration the ratio of surface area to volume and partially compensates for insensible water losses. The majority of maintenance fluids are then provided as 5% dextrose to limit sodium overload and provide sufficient free water to restore intracellular and interstitial requirements. The calculation for maintenance fluid administration is as follows:

- First 10 kg body mass 100 ml/kg/day
- Second 10 kg body mass 50 ml/kg/day
- All additional kilograms of body mass 25 ml/kg/day

As an example, the average 50-kg foal would receive 1000 ml/day for the first 10 kg of body mass, 500 ml/day for the next 10 kg of body mass, and 750 ml/day for the remaining 30 kg of body mass for a total of 2250 ml/day. This translates to an hourly fluid rate of about 94 ml/hr for maintenance. Most foals will generally receive 1.5 to 2 times maintenance but the rate must be adjusted higher if there are large ongoing losses. Potassium is generally supplied to the foal at 20 mEq/L of fluids administered, and then adjusted as needed.

Fluid and sodium requirements can be adjusted for ongoing losses exceeding the maintenance requirements. These losses can take the form of diarrheal losses and excessive urine output, such as those with glucose diuresis and renal damage resulting in an increased fractional excretion of sodium. The normal fractional excretion of sodium in neonatal foals is less than that of adult horses, usually less than 1% (J.E. Palmer, unpublished data) and normal foal urine (foals on a milk diet that are more than 24 hours of age) is generally quite dilute with a specific gravity of 1.005 or so. In the critically ill foal the sodium requirement can be met with as little as 140 mEq of sodium per day, about that administered in a single liter of normal equine plasma. One can address sodium deficits by separate infusion of sodium-containing fluids, although this may not
be necessary if one considers the sodium being administered in other forms, including drugs administered as sodium salts and any constant rate infusions (pressors, inotropes, etc.) that are being provided as solutions made with 0.9% sodium chloride.

The author has used this approach to fluid therapy in the NICU for the last few years and believes that the percentage of foals suffering from generalized edema, and related problems, has decreased. When using this approach to fluid therapy, the foal should be weighed at least once daily, although this is frequently impractical in practice, and fluid intake and output should be monitored closely as practical. Any larger than anticipated weight gains or losses should result in closer evaluation of the foal. Urine output will probably not approach the reported normal of 300 ml/hr for a 50-kg foal on a free choice milk diet because the free water administered is limited, unless the patient is experiencing diuresis (glucosuria, resolution of the syndrome of inappropriate antidiuretic hormone secretion, resolution of previous edematous state, renal disease). If possible, urine specific gravity should be measured several times daily and fractional excretion of sodium measured if renal injury or dysfunction is suspected. If the volume of urine produced by the patient is measured accurately, one can determine sodium losses accurately and can obtain creatinine clearance values.

In practice, fluid boluses are frequently used as maintenance of intravenous fluid lines and extension sets attached to the catheter and the foal can be challenging, particularly if the foal remains in a stall with the mare. This approach can be used safely, but the amount of fluid needed over the day needs to be carefully considered, particularly in foals with diarrhea where losses may be larger than anticipated. The total amount of fluids needed should be calculated for the day and then divided into bolus administrations ranging from every 3 to every 6 hours, depending on the condition of the foal; ideally bolus administration should be limited to 1-2 liters per bolus. Fluid choices should be dictated by the needs of the foal, but generally the sodium load administered with this route will be greater than that of constant rate infusion as dextrose should not be administered by bolus at large concentration, i.e., more than 1-2.5%. Potassium should not be added to fluids being administered as a bolus.

If the oral route is available for hydration, this can be used in foals that are not nursing but are able to tolerate enteral feeding. Placement of an indwelling small feeding tube (Kangaroo tube) will facilitate this, but the foal should be checked for the presence of reflux using a large diameter tube prior to placing the smaller feeding tube. These tubes are generally placed in the esophagus at the mid thorax level and not in the stomach. They also take some practice to learn to place, but once the technique is ‘conquered’ they are easy to place and maintain. In general a foal with a healthy gastrointestinal track will tolerate 10% of it body weight in milk or milk replacer divided into every 2 hour feedings (12 times per day). For a 100 pound foal, this would be:

100 lb x .10= 10 lbs

10 lb / 12 = 0.83 lb per feeding

There are 16 ounces in a pound, therefore the feeding should be ~13-14 ounces per feeding. If the foal tolerates this well, it can be gradually increased to 15 to 20 percent of its body weight.
over a few days if the foal continues to not nurse or drink from a bucket. If the foal shows evidence of colic or abdominal distention, feeding should be discontinued for a few hours and reinstated slowly. Water can be substituted for milk for rehydration purposes and milk or milk replacers can be diluted with water if needed for rehydration purposes, but keep in mind that the caloric support of the foal will be less in these circumstances. All enteral fluids should be administered under gravity flow only and the foal should be kept standing or in sternal recumbency at the least, for 5-10 minutes once the feeding is completed to prevent aspiration.

Older foals, those 30 days of age or older, can be approached more like the adult horse, as can weanling foals. In this group, the problem most likely to result in a need for fluid therapy is diarrhea. The bolus approach can be taken, considering a fluid requirement of 1-3 ml/kg/hour. However, if the foal can be successfully separated from the mare at this time in its life, constant rate fluid infusion (CRI) of a maintenance fluid, perhaps in concert with a 2.5-5% dextrose infusion, can be more readily provided and is more physiologic. The oral route can also be taken in this age group, again with the caveat that they should first be checked for reflux with a larger bore tube and that all fluid should be administered under gravity flow only.

**References**


