Fluid therapy and resuscitation in equine neonates

Ellen Paulussen, DVM, Dipl. ECEIM

One of the main dilemmas when evaluating a sick neonatal foal is whether or not fluid therapy is indicated. One must consider the variety of indications for fluid therapy, the different types of fluid, different routes of administration, the amount of fluid and the anticipated duration of the therapy.

Patient requirement for fluid therapy

The first challenge in patient evaluation is the accurate assessment of hydration status. The typical parameters used are mucous membrane color, capillary refill time, jugular refill time, pulse quality, temperature of the extremities, mental status and urine production. Fundamentally these are indicators of perfusion, rather than hydration, which is an important distinction given that there are situations, such as cardiogenic or vasodilatory shock, in which a well-hydrated patient can present extremely poor perfusion. The clinical signs most commonly used for the assessment of hydration are increased skin turgor (although not reliable in foals), tacky mucous membranes and sunken eyes. Further insights into hydration status can be gained by the measurement of urine specific gravidity. Values of greater than 1.010 indicate that the foal is retaining water and is likely not adequately hydrated. Urine output is another useful parameter, but it can be hard to gauge in foals that are not continuously monitored. The normal foal urinates at least once every 2 hours. Hypotension, considered a mean arterial pressure less than 60 mmHg, may be an indication of hypovolemia but can also result from decreased cardiac output or excessive venous capacitance.

Types of fluid

There are many choices of fluids and they fall into three broad categories: crystalloids, colloids and oxygen-carrying solutions. Crystalloid solutions contain electrolytes and nonelectrolytes (such as dextrose) that are capable of diffusing through the capillary wall into the interstitium, whereas colloid solutions contain larger molecules that do not readily diffuse and tend to remain within the vascular lumen. Oxygen-carrying solutions contain either red blood cells or other substances capable of delivering oxygen from the lungs to the tissues. In the majority of situations the most appropriate fluid will be a crystalloid solution. These solutions are classified based on their tonicity relative to normal plasma. Isotonic fluids will expand the ECF volume, expanding the circulating blood volume. Because these fluids contain large amounts of sodium they can result in hypernatremia, which has been associated with increased mortality and severity of illness in human patients. Hypotonic crystalloid solutions contain much less sodium and chloride, this can be very helpful because the lower sodium load decreases the risk of water retention and edema formation, and the lower chloride load decreases the risk of hyperchloremic metabolic acidosis. For this reasons hypotonic solutions are most useful for maintenance fluid therapy, in which there is less need for electrolyte replacement and more need for the provision of water. Hypertonic crystalloid fluids have higher electrolyte concentrations than plasma and have fewer indications for their use. The most commonly used hypertonic solution is hypertonic saline (NaCl 7.2%), which is primarily used to expand the circulating blood volume.

Route of administration

The most physiologic route of fluid administration is the enteral route, but it can be easy to overlook the utility of this route, especially in hospitalized patients. Generally, if the gut is working it should be used for at least whatever component of the fluid therapy is appropriate. IV administration will achieve the most rapid result because it allows for a large amount of fluid to be given, but IV access is associated with some complications such as thrombophlebitis and air embolism aspiration. Neither
subcutaneous nor intraperitoneal fluid administration is well tolerated in equine patients and these routes are rarely used.

**Dosage**

The factors that must be considered in determining the amount of fluids to administer are the volume needed for maintenance of normal body function, the magnitude of the existing fluid deficit and the ongoing losses potentially associated with the disease process (diarrhea, reflux, sweat). When designing the fluid therapy plan it is important to consider the maintenance fluid as separate from the replacement fluid plan, which includes both replacement of existing deficits and ongoing losses.

The calculation of maintenance fluid requirements in the foal can be approached in two different ways. The traditional approach is based on the accepted value of 3-5ml/kg/hour, the primary problem with this approach is that it represents a very broad range of fluid rates and may result in fluid overload if not monitored closely. A second approach is based on the Holliday-Segar formula, which provides a more conservative rate of fluid administration. With this calculation there is administered 100ml/kg/day for the first 10kg of bodyweights, 50ml/kg/day for each kilogram from 11-20kg and then 25ml/kg/day for each kilogram of bodyweight >20kg. The use of hypotonic crystalloid solutions is the most appropriate as maintenance fluid because of their lower amount of sodium and chloride. Supplementation of potassium however can be necessary, certainly if the foal is not nursing. The addition of potassium chloride at 20 to 40 mEq/L to a hypotonic maintenance solution is a reasonable starting point.

Using the clinical perfusion indicators mentioned previously one can derive a rough estimate of the degree of clinical dehydration. This approach yields estimates of dehydration ranging from 5% to >10% and these values can be used when calculating the estimated fluid deficit.

<table>
<thead>
<tr>
<th>Degree of dehydration</th>
<th>Skin testing</th>
<th>CRT</th>
<th>Mucous membranes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5%</td>
<td>1-3 sec</td>
<td>&lt; 2 sec</td>
<td>Slightly tacky</td>
</tr>
<tr>
<td>5-10%</td>
<td>3-5 sec</td>
<td>2-3 sec</td>
<td>Tacky</td>
</tr>
<tr>
<td>&gt;10%</td>
<td>&gt; 5 sec</td>
<td>&gt; 3 sec</td>
<td>Dry</td>
</tr>
</tbody>
</table>

Clinicopathologic testing can aid in refining the estimate of fluid deficit, with variables such as PCV, total plasma protein concentration, serum creatinine and lactate concentration all providing useful insights.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Overhydrated</th>
<th>Ideal</th>
<th>Underhydrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>/</td>
<td>80-120</td>
<td>&gt;140</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>Upward trend</td>
<td>&lt;56</td>
<td>/</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>20</td>
<td>35-45</td>
<td>&gt;45</td>
</tr>
<tr>
<td>Total protein (g/L)</td>
<td>&lt;30</td>
<td>50-80</td>
<td>&gt;80</td>
</tr>
<tr>
<td>Urine Output (ml/kg/h)</td>
<td>&gt;2</td>
<td>1-2</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Urine specific gravity</td>
<td>/</td>
<td>1.005-1.010</td>
<td>&gt;1.012</td>
</tr>
<tr>
<td>Plasma lactate (mmol/L)</td>
<td>/</td>
<td>&lt;2</td>
<td>&gt;5 (neonate), &gt; 2.5 (if &gt;4 days old)</td>
</tr>
<tr>
<td>Peripheral edema</td>
<td>Obvious</td>
<td>May be seen in some foals</td>
<td>/</td>
</tr>
<tr>
<td>Central venous pressure (cm H₂O)</td>
<td>&gt;8-12</td>
<td>3-8</td>
<td>0-5</td>
</tr>
<tr>
<td>BUN/Creatinine</td>
<td>/</td>
<td>normal</td>
<td>Increasing</td>
</tr>
</tbody>
</table>
Once a determination of the existing fluid deficit has been made, a replacement fluid plan can be formulated. Use of isotonic replacement fluid (LRS, Normosol-R and Plasmalyte A) is appropriate for this purpose. Rather than simply dividing up the calculated fluid deficit and administer it over a set period of time, it is more useful to administer boluses of replacement fluids at 20ml/kg over 10-30 minutes and then reassess the patient’s status to determine whether further boluses are required. Care should be taken not to exceed 60ml/kg total dose, unless there are compelling clinical reasons that this is indicated, such as ongoing losses. If greater than 60 ml/kg of fluid replacement is required and the patient remains hypotensive, then they should be considered non-responsive to fluid therapy and the initiation of inotrope and/or vasopressor therapy should be considered.

Monitoring of ongoing fluid therapy is very important and requires frequent assessment to ensure that the goals for fluid therapy are being achieved and to avoid the development of adverse outcomes such as fluid overload. Repeated assessment of the clinical indicators of hydration and perfusion status is readily performed and extremely valuable in monitoring fluid therapy.

**Neonatal resuscitation**

Cardio-pulmonary arrest in foals most commonly begins with respiratory arrest, which subsequently leads to cardiac arrest caused by asphyxia. Because of this the establishment of a patent airway and the provision of ventilator support is the initial priority in foals, rather than cardiac compressions.

The first challenge is in recognizing which foals require resuscitation, because early intervention before cardiac arrest is associated with a much higher likelihood of successful resuscitation, potentially as high as 50%. The clinical signs that may indicate the need for resuscitation include absence of breathing, irregular gasping, respiratory rate less than 10 breaths per minute, heart rate less than 40 beats per minute, irregular or absent muscle flaccidity, or lack of response to tactile stimulation. Other situations in which resuscitation may be required include primary lung disease, septic shock, hypovolemia, metabolic acidosis, hyperkalemia, hypoglycemia, vasovagal reflex and hypothermia.

If a foal fails to breathe spontaneously and regularly then an airway needs to established immediately and basic life support (BLS) should be implemented. The best approach to establish an airway is to pass a cuffed nasotracheal tube. Ventilation should be provided with a self-inflating valved manual resuscitation device at 10 breaths per minute. Excessive ventilation negatively affects cardiac return and coronary perfusion and has been associated with worsened outcome. As many as 90% of foals that require resuscitation will respond to ventilator support alone. If a heartbeat is absent or the rate is too low, then it is important to immediately initiate thoracic compressions. A rapid rate of 100 compressions per minute is advised, but compressions should be stopped every 2-3 minutes and should be resumed within 10 seconds. If the foal is not responding to Basic life support then more aggressive measures (Advanced life support) are indicated. These may include administration of pharmacologic agents and implementation of improved monitoring. Many drugs have been used empirically in foals resuscitation, but none has been specifically studied in the foal. The utility of many of these agents is debatable, either because they are directed toward primary cardiac dysfunction, which is rare in foals, or because their use in human cardiopulmonary resuscitation has been discontinued. The drug that is most likely to be used is epinephrine. Vasopressin has been used either in place of, or in combination with, epinephrine. Doxapram has been commonly used in foal resuscitation as a respiratory stimulant, but is contra-indicated because it does not reverse secondary apnea and has been shown to decrease cerebral blood flow and increase cerebral oxygen consumption.
Basic Life Support

- Respiratory arrest
  - Establish airway
  - Ventilate at 10 breaths/min
  - Heart rate >50 bpm or >40 bpm and increasing, not spontaneously breathing
    - Reassess cardiac and respiratory function at 30 seconds – then every 2 min
    - Cardiac arrest – pulseless electrical activity
      - Initiate chest compressions – 100/min

Advanced Life Support

- Establish venous access
- Epinephrine 0.01 mg/kg every 3-5 min +/- Atropine 0.02 mg/kg IV once
- Place ECG
  - Attach capnograph – monitor EtCO₂
- Rhythm check every 2-3 minutes

- Asystole
  - Pulseless electrical activity
  - Continue chest compressions
  - Vasopressin 0.8 U/kg once then Epinephrine 0.01 mg/kg every 3-5 min
  - Greater than 10-15 min CPR = Failure

- Ventricular fibrillation
  - Pulseless ventriculartachycardia
  - Defibrillate 2 J/kg
  - 2nd attempt - increase to 4 J/kg
  - Resume chest compressions

- Perfusing rhythm
  - Increasing EtCO₂
- Stop compressions and monitor
- Heart rate >60 bpm
- Respirations >16 bpm

Success – Provide appropriate supportive care and monitoring

Bpm, beats per minute; EtCO₂, end-tidal CO₂.
**Defibrillation**

Defibrillation is indicated in cases of ventricular fibrillation and pulseless ventricular tachycardia. Access to appropriate equipment is often limited, however. The widespread availability of human automated electrical defibrillators may alter this situation, but at this time there are no published studies regarding their use in foals. When performing defibrillation the cardiac compressions and ventilation should continue until the moment of defibrillation and resumed immediately afterward. The initial charge should be 2 J/kg, which should be increased to 4 J/kg for subsequent attempts.

**Monitoring Resuscitation**

Patient status during resuscitation is extremely dynamic, requiring constant reassessment, and it can be difficult to monitor for return of spontaneous circulation and spontaneous respiration without interfering with the process of resuscitation itself. Following initiation of resuscitation efforts cardiac and respiratory function should be reassessed at 2- to 3-minute intervals unless the foal shows obvious signs of response. Monitoring via electrocardiography can be challenging, because electrical activity does not necessarily represent effective cardiac contractility, which is a phenomenon termed *pulseless electrical activity*. Respiratory efforts are much more readily observed and their effectiveness should be subjectively evaluated. One technique that can greatly facilitate monitoring during resuscitation is the monitoring of end-tidal CO2 (EtCO2), if capnography is available. During resuscitation a reasonable target for EtCO2 is 10 mm Hg, because this indicates that an adequate degree of perfusion and ventilation is being achieved. If resuscitation is successful then a rapid increase in EtCO2 toward the normal range will be observed, indicating that both perfusion and ventilation are improving. A decrease in EtCO2 during resuscitation indicates inadequate ventilation and perfusion, requiring reevaluation of how resuscitation is being performed. If no response is detected after 10 to 15 minutes of resuscitation it is extremely unlikely that the patient will respond with further efforts.

**Post resuscitation Support**

Following successful resuscitation the patient should be considered at high risk because of the presence of any primary, initiating diseases and the likelihood of secondary hypoxic injury. Appropriate medical care and monitoring are critical during this period of time. Foals should receive intranasal insufflation of humidified oxygen at 5 to 10 L/min until they have been demonstrated to be stable with adequate cardiopulmonary function. Fluid therapy will likely be of benefit in ensuring normovolemia and supporting cardiovascular function. Care should be taken to avoid overhydration, because these patients may be at risk of pulmonary edema. Pressor and inotrope therapy may be indicated if cardiovascular function is inadequate. Glucose support is important, especially in neonates, but care should be taken to avoid hyperglycemia. If resuscitation occurred in the field then serious consideration should be given to immediately referring the foal to a facility equipped to provide intensive care.