

IMMEDIATE CARE OF THE COMPROMISED FOAL

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The equine neonate in a compromised condition secondary to sepsis, dehydration or uroperitoneum can be a complex treatment challenge. The foal will initially show little signs that it may be sick to the owner. It is not until the foal experiences hypotensive shock that the owner notes a problem with their foal. That is where we get called to provide immediate care. The most important diagnostic modality that a veterinarian can do when assessing the compromised patient is a proper physical exam. Once the physical exam has been performed then further diagnostic and treatment plans can be formulated.

Hypotensive Shock and Fluid Replacement

Resuscitation procedures will vary with the primary cause. However, precise definition of the causal factors may require time in a situation where prompt initiation of fluid therapy is critical. Crystalloids (solutions containing electrolytes and/or glucose) and/or colloids (solutions containing large molecular particles, such as proteins) are used when volume replacement in hypovolemic and dehydrated foals is warranted.

In hypovolemic septic shock sequential boluses of 10-20ml/kg of crystalloid replaced (Lactated Ringer's Solution, Plasma-Lyte 148 or Normosol-R) over 10-30 minutes should be given. Re-evaluation of the animal's perfusion should be assessed by signs of regional perfusion, improved pulse quality, urine production and mental behavior. It is not uncommon for further fluid boluses to be needed to obtain adequate perfusion. One-half strength Ringer's, 5% dextrose and 0.45% saline should never be used as resuscitation fluids due to the potential to cause life threatening cerebral edema if given too rapidly. Only 10% of the crystalloid volume infused will still be in the circulation after 1 hour. The other 90% will be divided equally between the intracellular and interstitial spaces.

The use of colloids such as hetastarch and Oxyglobin (Biopure) are commonly used in resuscitation from shock. These colloids are preferred for the treatment in shock compared to the crystalloids because they remain in the vascular space for a much longer period of time.

Hetastarch is a polymeric molecule made from a waxy species of maize or sorghum and is composed primarily of amylopectin (98%) and has an average molecular weight of 450,000 daltons (d). It is a highly branched polysaccharide closely resembling glycogen. Its colloid osmotic pressure (COP) is 30 mm Hg. In foals the plasma has a normal COP of 18.8 +/- 1.8 mmHg. Following an IV dose, small particles of hetastarch (50,000 d) are

rapidly excreted in the urine after administration. In humans 46% of an administered dose is excreted in the urine by 2 days and 64% by 8 days. Larger particles remain in circulation for a longer period of time depending on their absorption by the liver and spleen. Blood amylase also degrades larger particles into smaller starch polymers and free glucose. The dose used at our clinic ranges from 5 to 10ml/kg (500ml for a 50-kg foal) which may be administered over minutes to an hour depending on what the clinical situation demands. Hetastarch can reverse changes in microvascular permeability caused by oxygen derived free radicals during reperfusion injury. It also decreases plasma concentration of soluble adhesion molecules, thus decreasing leukocyte-endothelial adhesion and improves microcirculation.

Hemoglobin-Based Oxygen carriers (HBOC) such as Oxyglobin provide both a colloid and oxygen carrying effect. Oxyglobin has a low viscosity (because it does not contain red blood cells) so it flows through the microcirculation significantly better than whole blood. The colloidal effect of HBOCs helps them expand the intervascular compartment. It is estimated that within 40 minutes of an infusion of HBOC, the total plasma volume is increased by 20ml/g of HBOC administered. For every 10ml of Oxyglobin infused (1.3 g of HBOC), 26 to 27 ml of plasma will be maintained in the circulation. For resuscitative purposes at our clinic we have used dosages of 3-5 ml/kg Oxyglobin (1 to 2 – 125 ml Bags of Oxyglobin / 50 kg of body weight). Oxyglobin has a very long shelf life (3 years) at ambient temperatures of 35 to 86 F.

Exact maintenance fluid requirements in the neonatal foal are unknown. Currently many protocols are used to estimate fluid requirements in this age group. A maintenance fluid requirement of 80 to 120 ml/kg/day or 3 to 5 ml/kg/hr is what I use in our NICU (4 liters of intravenous fluids/day/50kg foal) to maintain the fluid needs for an ill foal. There is a high degree of individual variability and therefore critically ill foals should be monitored using clinical exam findings, central venous pressure, mean arterial pressure, urine output (see acute renal failure), blood lactate levels as well as the hematocrit and total protein values. The use of these diagnostic values alone should not dictate fluid needs, but should be used in combination to establish appropriate fluid therapy.

Glucose is beneficial for all compromised neonates. The main challenge is preventing the patient from becoming hyperglycemic after the administration of glucose. Blood glucose levels are lowest usually 2 to 4 hours after birth. A normal foal will begin glucogenesis without a problem, but the neonate suffering from a disease may not make the transition to glucogenesis and may become dangerously hypoglycemic. The use of a 2.5% dextrose solution can be administered during the initial resuscitation stage. We would routinely add 50cc 50% dextrose to a 1 Liter bag of our replacement fluids (LRS, Plasma-Lyte 148 or Normosol R) to obtain the 2.5% dextrose solution. The use of 5% dextrose as a resuscitation fluid could potentially cause life threatening cerebral edema when given rapidly.

Perinatal Asphyxia

Perinatal Asphyxia Syndrome produces hypoxic ischemic encephalopathy (HIE) resulting in neurological deficits ranging from hypotonia to grand mal seizures. Foal's affected with perinatal asphyxia also experience gastrointestinal disturbances ranging from mild ileus and delayed gastric emptying to severe, bloody diarrhea and necrotizing enterocolitis (NEC). Renal compromise accompanied by varying degrees of oliguria is also a sequela to asphyxia.

Any discussion of the pathogenesis of perinatal HIE requires the definition of certain terms regarding variations in blood or tissue concentration of oxygen. **Hypoxia** is the partial (hypoxemia) or complete (anoxemia) lack of oxygen in the brain or blood. If the hypoxemia is severe enough, initially peripheral tissues and ultimately brain tissue will develop an oxygen debt, leading to anaerobic glycolysis and the production of lactic acidosis. **Asphyxia** is the state in which placental or pulmonary gas exchange is compromised or and if gas exchange ceases it may progress to hypoxemia. **Ischemia** is a reduction in or cessation of blood flow to an organ (brain), which compromises not only oxygen delivery to tissue but substrate delivery as well.

The fetus adapts to a relatively hypoxic environment in utero by increased oxygen affinity of fetal hemoglobin, increased ability to extract oxygen from the blood and a greater tissue resistance to acidosis. Similar to the redistribution of blood flow in a diving seal, the severely asphyxiated fetus and neonate are able to redistribute oxygenated blood away from less vital organs (lungs, kidneys, skin and bowel) to more vital organs (heart, brain and adrenals). As a result of this protective mechanism, multiple organs may sustain injury. The equine fetus appears to have an oxygen demand "reserve" in that, under conditions of reduced oxygen availability, it decreases its rate of growth and decreases its oxygen consumption. This form of in utero growth retardation (IUGR) is termed *disproportionate*. The fetus is stunted and presents with a disproportionately large head, little muscle mass, small frail body and little to no fat. If the in-utero asphyxia is severe the fetus will not be able to sufficiently compensate and the CNS will be compromised. Compromise of the fetal CNS will lead to sequential loss of fetal reflexes with the most complex, oxygen demanding fetal activities affected first. Fetal heart rate is adversely affected first, then fetal breathing followed by generalized fetal movements and fetal tone. Many factors including gestational age of the fetus, degree and duration of hypoxia determine the severity of clinical signs and CNS lesions.

Passage of meconium into amniotic fluid by the equine fetus may be a normal event or may occur as a result of a hypoxic event. In a hypoxic-ischemic event cardiac output is redistributed in the fetus away from less vital organs such as the bowel. This may result in intestinal ischemia followed by transient hyperperistalsis, anal sphincter relaxation, and meconium passage.²

In an uncompromised neonatal animal, and presumably in the human fetus or newborn, uncomplicated hypoxemia, no matter how severe, never causes brain damage. In an uncompromised fetus or neonate blood flow is redistributed to the heart and brain during

hypoxemia . Cardiac function is preserved because the heart has high endogenous stores of glucose and glycogen. Studies in fetal animals do however support the notion that brain damage does occur when cerebral ischemia, secondary to systemic hypotension is superimposed on the hypoxemia.²

Adenosine triphosphate (ATP) is the primary energy modulator of all cells including neurons. In tissue hypoxia ATP production by oxidative phosphorylation is curtailed, with concurrent increases in cellular adenosine diphosphate (ADP) and adenosine monophosphate (AMP). The loss of cellular ATP during hypoxia-ischemia severely compromises metabolic processes that require energy for their completion. Thus, ATP-dependent Na^+ efflux through the plasma membrane in exchange for potassium is curtailed resulting in accumulation of sodium, chloride and water (cytotoxic edema) inside the cell. Intracellular sodium and chloride ions and water accumulate, resulting in electrochemical gradients that cannot be re-established. Prolonged hypoxia-ischemia may result in cell death of the capillary endothelium and tight junctions. This prolonged hypoxia-ischemia may result in extracellular edema (vasogenic edema). How long a cell can survive in this situation is not known, as other factors influence cellular integrity. The role of extracellular edema and increased intracranial pressure in foals with HIE is currently being debated with no consensus at this time.

Recent *in vitro* and *in vivo* studies have revealed that the excitatory amino acid neurotransmitter glutamate is a major contributor to HIE injury. Under normal conditions, most of the glutamate remains within neuronal and glial cell bodies, where it is prevented from activating the glutamate receptors. There are at least four glutamate receptors. (Figure 1). Three of these receptors have been named KA, NMDA and AMPA. All three of these receptors are coupled to ion channels and gate flux of cations when activated. The uptake pumps transport synaptically released glutamate back across the cell membrane so that the concentration of free glutamate is low. Under conditions of prolonged hypoxia-ischemia the energy dependent uptake pumps gradually fail. Neurons depolarize and leak glutamate, which cannot be removed rapidly from the extracellular space. The neurotransmitter glutamate which has “leaked” into the extracellular space can now bind to one of its receptors (KA, NMDA and AMPA) . Once activated these glutamate receptors activate the sodium and potassium ion channels. More critical however, is the influx of calcium into the cell through glutamate-gated channels, especially the NMDA receptor. Calcium, in turn, sets in motion a cascade of biochemical events that cause the death of a neuron.

Excessively excited by high levels of glutamate, neurons and other cells with appropriate glutamate receptors can be sent into a death spiral. The mitochondria are the major buffers of intracellular calcium and will become overloaded during cytoplasmic calcium flooding from the opening of the NMDA calcium channels. The diminished mitochondrial function can lead to decreased energy to maintain ion gradients, potentially perpetuating a cycle of membrane depolarization and NMDA receptor channel opening. The increased free cytosolic concentration of calcium activates numerous intracellular reactions, including activation of lipases, proteases and endonucleases, which disrupt the structural integrity of the cell. When these intracellular reactions are in excess viability

of the neuron is seriously compromised. Calcium also contributes to the formation of oxygen free radicals via the formation of xanthine and prostaglandins.

At present, a rational approach to the management of hypoxic-ischemic encephalopathy in the fetus or newborn does not exist. The problem of preserving brain function during neonatal asphyxia is that we do not know the therapeutic window for intervention. In the term human infant the therapeutic window is short lasting only 4 to 8 hours. The therapeutic window for premature animals may be even smaller. Treatment of HIE in foals should include therapies to preserve brain function and other damaged organ systems. Treatment strategy employs a combination of therapies because of the multifaceted nature of hypoxic-ischemic brain injury.

ALLOPURINOL: 40 mg/kg PO within 2-3 hours of birth. Mechanism of action has been explained primarily by its ability to inhibit xanthine oxidase.

ASCORBIC ACID: 100mg/kg/day IV Inhibits neurotransmitter binding to NMDA receptors. In the fetus, ascorbic acid is one of the principal antioxidant systems. Plasma ascorbic acid concentrations in the brain are approximately 10 fold-those in plasma. The optimal dosage of ascorbic acid for neuroprotection is not known. In high-risk human premature infants a dose of 100mg/kg/day was found to be safe.

VITAMIN E: 4,000 IU PO SID (Neonate) or 10,000 IU PO SID (DAM) Vitamin E is an antioxidant that is synergistic with ascorbic acid. While ascorbic acid is the principal antioxidant in the aqueous environment, vitamin E decreases the amount of lipid peroxidation and is the principal antioxidant in the lipid environment. The main problem with vitamin E is that it is lipid soluble; for an effective dose to reach the brain or circulation, vitamin E needs to be given for some days before the ischemic insult. There may be a role in the setting of early fetal distress and vitamin E supplementation given to the mare.

MAGNESIUM SULFATE 50mg/kg IV infusion for 1st hour then 25mg/kg continuous rate infusion (CRI) Mg²⁺ has a normal voltage-dependent (Figure 2) blockade of the NMDA receptor. This blockade of the NMDA receptor is compromised in injured neurons. The Mg²⁺ blockade can be partially restored by increasing extracellular Mg²⁺ concentration. There is a lack of consensus in human medicine regarding the use of magnesium in the treatment of infants with HIE. The current dose regime has been noted to be safe in foals when infused over 3 days. At this time no beneficial conclusions can be drawn from the use of this treatment in HIE. This treatment appears to have clinical benefit but there is no data to support or refute its use.

THIAMINE 1 gram IV in 1 L of Fluids SID. Thiamine is thought to be neuroprotective due to its action of increasing activity of the adenosine triphosphate dependent sodium pump, thereby regulating ion uptake and decreasing cellular water.

SELEGILINE (L-Deprenyl) 5 mg orally SID for 1-5 days. Enhances superoxide dismutase and catalase activity. Reduce neuronal apoptosis post injury.

DMSO 0.25 to 1 gram /kg IV Q6 to Q12 hour as 10% solution (100ml per liter) It has been used for treatment of cerebral edema and suspected increase in intracranial pressure (osmotic diuretic). DMSO is a hydroxyl radical scavenger and may theoretically prevent some cellular damage attributed to oxygen radical generation.

MANNITOL 0.25 to 1 gram as 20% solution Q6 to Q12 hour as an IV bolus over 15-20 minutes. Osmotic agent, which has been specifically used for the treatment of cerebral edema. It also has some neuroprotective properties.

DIAZEPAM 0.11 to 0.44 mg/kg IV or Phenobarbitol 12mg/kg IV Loading dose then 2-7mg/kg IV Q 12h, give slowly, monitor serum concentrations (maintain serum levels 15-40 mcg/ml) Use for seizure activity

Hyperbaric Oxygen Therapy 1.5 to 2 ATM for 45min to 1 hour SID/BID

Internists have different philosophies on how to treat HIE. For field practitioners who have identified a foal suffering from HIE I would recommend the use a liter of Normosol or LRS with 50cc 50% dextrose, 2cc Thiamine, 20cc Vitamin C and 2cc MgSO₄. This initial treatment plan could benefit the foal by supplying energy, allowing blockage of the NMDA receptors (MgSO₄), antioxidants (Vitamin C) and increasing activity of the adenosine triphosphate dependent sodium pump (Thiamine).

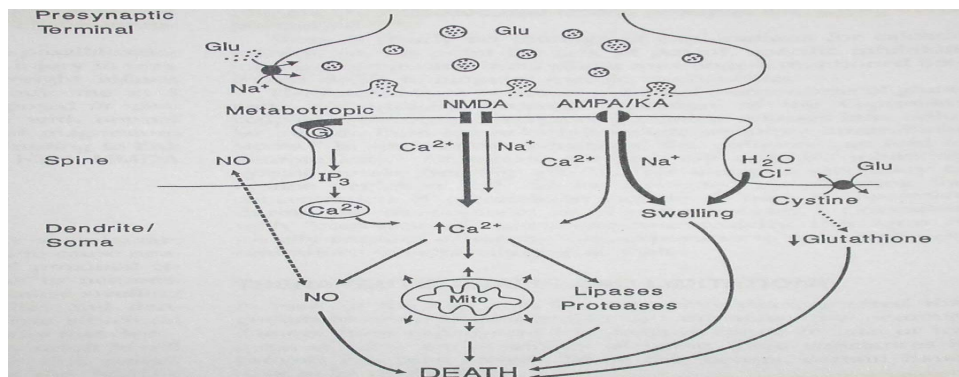


Figure 1: Schematic drawing of the Glutamate receptors NMDA, AMPA and KA illustrating how excessive stimulation of these receptors can lead to necrosis of the neuron.

Acute Renal Compromise

Urinary dysfunction is common in neonatal foals. The kidney is the most damaged organ in asphyxiated full-term human infants. Acute renal failure (ARF) is characterized by a sudden impairment in renal function leading to an inability of the kidneys to excrete nitrogenous wastes. Acute renal failure may occur because of **prerenal** (decreased renovascular flow), **intrinsic** (renal parenchyma/acute tubular necrosis) and **post renal disorders** (obstructive). Some foals < 24 hours of age without severe renal disease can have creatinine concentrations >15mg/dl. The cause of this increased creatinine level is most likely associated with placental insufficiency. The creatinine levels tend to decrease over the next 3-5 days without medical intervention.

Prerenal ARF is the most common type of renal failure observed in the equine neonate. Prerenal ARF is characterized by inadequate renal perfusion which must be diagnosed quickly and aggressively treated. Failure to initiate therapy may result in irreversible parenchymal damage or death. The most common causes of prerenal ARF are dehydration, hemorrhage, septic shock, necrotizing enterocolitis, as well as medications (NSAIDs) that may reduce renal blood flow (RBF). Decreased renovascular flow in neonatal foals usually causes a decrease in urine production. All critically ill foals should be monitored closely for urine output (normal 6ml/kg/hr) and changes in serum electrolytes and creatinine. Failure of the serum creatinine to fall or persistent increase in serum creatinine suggests impairment of renal function. In general, each doubling of the serum creatinine level represents a 50% reduction of GFR. For example a rise in serum creatinine from 1.5 to 3.0 mg/dL represents a 50% reduction in GFR. The monitoring of urine production can be used as adjunct to the measurement of systemic blood pressure and plasma lactate in evaluating whole body perfusion. The production of adequate or large volumes of urine after appropriate crystalloid-colloid therapy in critically ill foals is a good marker of improved systemic perfusion.

The clinical presentation of ARF varies depending on the cause, severity, previous therapy, and associated diseases predisposing the renal injury. Variable signs of ARF include development of listlessness, anorexia, ileus and diarrhea. One of the most important considerations of the management of ARF is to **PREVENT** its development. Clinicians must be on e guard to recognize circumstances that predispose to acute renal failure, actively alter those circumstances, and monitor patients at increased risk for early indications of renal compromise. If the foal has already developed ARF from a prerenal disorder, then initial treatment efforts should focus on correcting existing hypotension, acidosis, and hypoxemia to reduce renal vasoconstriction and improve perfusion.

Intravenous crystalloids and colloids should be administered to improve perfusion and urine production (Refer to Fluid Replacement section). To monitor the urine production in the patient either a foley balloon catheter can be aseptically placed or sequential ultrasonographic examination of the bladder could be performed. If urine production does not occur soon after therapy is begun, then either Central Venous Pressure (CVP) (normal < 10-12 cm H2O) or changes in body weight can be monitored. Hypervolemia is a common complication of overzealous fluid administration or improper monitoring of fluid balance. Once administered, an excessive load may be very difficult to correct if the

animal has no effective urine output. Failure to induce a significant diuresis after volume replacement indicates that either the parenchymal damage is severe, the initial fluid deficit was underestimated or the foal has severe hypoperfusion. If aggressive fluid loading does not return perfusion, inopressor therapy may be helpful. Dobutamine (3-10 $\mu\text{g/kg/min}$) and dopamine (3-10 $\mu\text{g/kg/min}$) should be administered together intravenously. Studies in other species have documented that use of these inopressors do not increase the chances of survival from ARF. However in our clinic we have observed increases in urine production by adding a bottle of dobutamine (250mg/20ml) and a bottle of dopamine (200mg/5ml) in a 500ML bag of normosol (or 0.9% saline) and administer it a CRI of 0.45ml/kg/hr. At this rate you will be administering 3 $\mu\text{g/kg/min}$ of dopamine and 3.6 $\mu\text{g/kg/min}$ dobutamine to your patient. We have increased our rate of infusion to 9 $\mu\text{g/kg/min}$ on patients that may be severely septic and refractory to the initial rate of infusion. Adverse reactions include tachycardia and occasional arrhythmias.

Furosemide can be used in conjunction with inopressors to increase urine production. Furosemide has limited effects on GFR in anuria because it must gain access to the renal tubule. There is no standard treatment regimen for furosemide in either human or veterinary medicine. We have used furosemide at doses of 1mg/kg IV Q 60 minutes for 3-4 hours to Q 4-9 hours. Once the patient becomes oliguric (2-4ml/kg/hour) then osmotic diuretics (Mannitol 20%) may be given to help increase urine production. We use 20% Mannitol at a dose of 0.5 to 1 gram/kg IV BID to QID administered as a bolus.

Aminophylline (theophylline) is an adenosine antagonist which reduces the renal dysfunction in full term human neonates with perinatal asphyxia. In rabbits and rats renal adenosine acts as a vasoconstrictive metabolite in the kidney after hypoxemia and/or ischemia, contributing to the fall of glomerular filtration rate (GFR). The vasoconstriction can be inhibited by the nonspecific adenosine receptor antagonist, theophylline. We have subjectively seen clinical response (increased urine production) with treatment using a dose of 5-10 mg/kg IV diluted in fluids and given 3-4x daily. If the aminophylline treatment is continued for a prolonged time (> 2 days) then serum theophylline concentrations should be monitored and maintained at < 15 $\mu\text{g/ml}$. If these medical treatments are unsuccessful in increasing urine production then the use of Vasopressin may be warranted. Vasopressin (Antidiuretic hormone) is a non catecholamine vasopressor that is a very potent vasoconstrictor through its action on peripheral V1a receptors. Vasopressin also acts on V2 receptors in the kidney to result in free-water reabsorption. Clinical use of vasopressin at a rate of 0.25-1 mU/kg/min causes an increase in arterial pressure in many hypotensive patients.

Nephrotoxic drugs should not be administered to foals that are severely hypotensive. Dosage-intervals should be adjusted for drugs that are excreted through the kidneys. (See the package insert or refer to the Physicians Desk Reference (PDR))

Acute tubular necrosis (ATN) is the most common cause of **intrinsic ARF** in human neonates. Causes of ATN include perinatal asphyxia, sepsis, prolonged prerenal state and nephrotoxic drug administration. The pathophysiology of ATN is complex and appears to involve renal tubular cellular injury, alterations in adhesion molecules, and changes in

renal hemodynamics. Other causes of intrinsic renal failure in the new born foal include renal dysplasia, polycystic kidneys and renal venous thrombosis.

Post renal disorders (obstructive) can also be seen in equine neonates. The most common cause of obstructive acute renal failure is that of a neurogenic bladder which may result in hydroureter and hydronephrosis. The cause of the neurogenic bladder is poorly understood but may be caused by hypoxic ischemic disease to an area of the bladder wall, spinal cord and/or brainstem that is responsible for the parasympathetic relaxation of the urethral sphincter. Management consists of placement of an indwelling urinary catheter and treatment for perinatal asphyxia syndrome. Uroperitoneum can occur when the integrity of the bladder wall is compromised.

Uroperitoneum had been long recognized in the equine species, neonates being most affected. The true incidence of uroperitoneum in the neonate is unknown but is estimated to be less than 1%. Disruption of the ureters, bladder, urethra or urachus can lead to leakage of urine into the peritoneal cavity. Defects of the bladder are most commonly reported. Common clinical signs may include dysuria, depression, stranguria, bilaterally symmetrical ventral abdominal distention, abdominal pain and ileus. Anuria is not typical, whereas pollakiuria is characteristic. In Dr. Kablack's retrospective study of uroperitoneum in the equine neonate she noted that 45% of the cases had a positive sepsis score greater than 16 with overt signs or septicemia and multi-organ involvement.

Ruptured urinary bladder can be considered as a medical emergency because of the severe electrolyte (hyponatremia, hypochloremia, hyperkalemia and metabolic acidosis) and acid base disturbances associated with cardiovascular impairment (arrhythmias).

Fluid shifts into the peritoneal cavity results in dehydration and hypovolemia manifested by polydipsia, decreased skin turgor, tachycardia, weak pulses and prolonged capillary refill time. Increased intra-abdominal pressure compromises cardiopulmonary function resulting in an increased respiratory effort. If the cause for the uroperitoneum is not corrected convulsions, coma and death can result due to severe metabolic derangements and cardiopulmonary dysfunction. Diagnosis of uroperitoneum may be confirmed with abdominal ultrasonography, Chemistry Panel (Azotemia), peritoneal tap (Creatinine in peritoneal fluid is $>$ or $= 2\times$ that of the serum), contrast radiography and /or retrograde injection of sterile new methylene blue. Initial management is to correct metabolic derangements to restore normal cardiopulmonary function before surgical correction.

Plasma volume expansion with normal or hypertonic saline and administration of dextrose, insulin and bicarbonate solutions to correct hyperkalemia and metabolic acidosis are recommended. We use a 0.9% saline with 5% dextrose solution initially. This solution will help drive potassium into the cells (The dextrose will help release endogenous insulin) and help resolve the hyponatremia. Abdominal drainage is often necessary to reduce abdominal distention, improve cardiopulmonary function and eliminate nitrogenous waste products. ADEQUATE volume expansion prior to and during large volume abdominal drainage is essential to prevent circulatory collapse from blood volume redistribution to the splanchnic vasculature.

Primary postoperative concerns include improving hydration and metabolic status, avoiding breakdown of bladder repair and preventing the development of peritonitis. Although uncommon in neonates peritonitis can develop following uroperitoneum. Urine

is irritating to the peritoneal cavity and can predispose the animal to a bacterial infection. To help alleviate the stranguria noted post-operatively phenazopyridine 4mg/kg PO TID is recommended. Prognosis is usually good unless peritonitis develops then the prognosis is decreased (50% survival).

REFERENCES:

- Fanaroff, A , Martin R: *Neonatal-Perinatal Medicine. Diseases of the Fetus and Infant*. Missouri: Mosby, 2002 ; 847-899
- Valla, W: Peripartum Asphyxia: In: Turner AS, ed. *Perinatology. Vet Clinics North America* : 10:1 187-215, 1994
- Johnston, M , Trescher W, Ishida, A, Nakajima, W: The Developing Nervous System: A series of Review Articles. *Pediatric Research* , 49:6 735- 741 2001
- Tan, S and Parks, D : Preserving Brain Function During Neonatal Asphyxia: In: Jain L, Kennon W, ed. *Resuscitation of the Fetus and Newborn. Clinics in Perinatology* 26:3 733-747 1999
- Mink, RB: Advances in pediatric resuscitation. *Clinical Pediatric Emergency Medicine* 2001 2:2: 129-135
- Zhu J, Hamm RJ, Reeves TM, Povlishock: Postinjury administration of L-Deprenyl improves cognitive function and enhances neuroplasticity after traumatic brain injury. *Exp Neurology* 2000, 166, 136-152
- Yocobi A, Stoll RG: Pharmacokinetics of hydroxyethyl starch in normal subjects. *J Clin Pharmacol* 22:206-212, 1982
- Jones PA : Oncotic, hemodilutional, and hemostatic effects of isotonic saline and hydroxyethyl starch solutions in clinically normal ponies. *American Journal of Veterinary Research* 58:5 541-549, 1997
- Perkins G, Divers T: Polymerized hemoglobin treatment in a foal with neonatal isoerythrolysis. *J Vet Emerg Crit Care* 2001, 11(2) : 141-145
- Belgrave RL, Bayly WM, Hines MT: Effects of Oxyglobin administered in ponies with normovolemic anemia. *Journal Veterinary Internal Medicine* 2001, 15:289
- Divers TJ and Perkins GP: Urinary and Hepatic Disorders in Neonatal Foals. *Clinical Techniques in Equine Practice* 2003, 2:1 67-80

Magdesian KG and Madigan JE: Volume Replacement in the Neonatal ICU: Crystalloids and Colloids. *Clinical Techniques in Equine Practice* 2003, 2:1 20-30

Muir W W III: Cardiopulmonary resuscitation and the prevention of hypotensive emergencies in horses, in *Proceedings Annu Conv Am Assoc Equine Pract*; 1984;30:117-125

Jose-Cunilleras E, Hinchcliff KW: Renal pharmacology. In: Whittam T, ed. *Clinical Pharmacology and Therapeutics* . *Vet Clin North Am Equine Pract*; 1999;15;3:647-64

Frazer ML: Acute renal failure from leptospirosis in a foal. *Aust Vet J* 1999 Aug;77(8):499-500

Cook V., Divers T., Chevalier H. and Woodie J.B.: Relationship between colloid oncotic pressure, serum albumin and serum protein concentration in postoperative colic patients. *J Vet Emerg Crit Care*; 2002;12;4:276-278

Madigan JE: *Manual of Equine neonatal Medicine 3rd ed.* Woodland, CA, Live Oak Publishing, 1997
