

School of Veterinary Medicine | University of California, Davis

Horse Report

May 2015

NEONATAL
CRITICAL CARE
ISSUE



UC DAVIS

VETERINARY MEDICINE

Center for Equine Health

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Dr. Claudia Sonder

DIRECTOR'S MESSAGE

Horses were designed to run. Within hours of birth, they have the precocial ability to escape predators, seek shelter and keep pace with their mothers. This is in sharp contrast to human infants who require years of care to achieve the same milestones. Mares deliver their young in 20 minutes, at a moment of their choosing. I can personally recount 48 hours of labor before I laid eyes upon my firstborn. As species we couldn't be more different in this regard, and yet, we have borrowed from the human medical field much of what we know about equine neonatology.

UC Davis is the home of one of the first equine neonatal units in the country and has a long history of leading advancements in our ability to prevent, diagnose and treat life-threatening neonatal conditions. The dramatic change from the sedate intrauterine environment to the cold, hard outside world requires that many processes align for success.

Researchers at UC Davis have recently discovered a potential explanation for one of the most difficult equine neonatal conditions in foals: neonatal maladjustment syndrome (NMS), commonly known as dummy foal syndrome. Foals affected by NMS fail to display the precocial behaviors necessary for survival and often present a therapeutic challenge requiring hospitalization and support. Our investigators are looking at a series of events that signal the foal to awaken, and the possible associations between foal fetal awakening and neurodevelopmental disorders in human infants. If a connection can be made, then equine veterinary medicine may help advance medical options for children.

The greatest gifts the equine NICU at UC Davis has given us have been the tools that veterinarians can use to keep mares and foals healthy and prevent



perinatal risk. More than ever, horse owners and veterinarians are equipped to keep foals out of the NICU. This *Horse Report* highlights the steps you can take to maximize the health and well-being of your foal and describes the options for early intervention and treatment in the field as well as the indications for referral for more advanced care.

Years of experience with foals referred to the William R. Pritchard Veterinary Medical Teaching Hospital at UC Davis has produced a neonatal unit that is pushing the boundaries of critical care, and the story of Amal detailed in this *Horse Report* highlights how far equine neonatal medicine has come.

UC Davis has a long history of leading advancements in our ability to prevent, diagnose and treat life-threatening neonatal conditions. The dramatic change from the sedate intrauterine environment to the cold, hard outside world requires that many processes align for success.



If your foal should develop complications, there is no finer place than the world-class equine NICU at UC Davis, staffed by board-certified specialists with expertise in critical care. The NICU team is experienced in successfully handling post-birth complications that require the high-level intensive care a sick foal needs. Specially trained technicians provide round-the-clock monitoring, oxygen, IV fluids, IV antibiotics, and nutritional support.

It is exciting to see veterinary and human medicine come together with a synergy that changes outcomes for multiple species. As an equine veterinarian, I am thankful for the opportunity to make a difference in a life so new and full of potential.

CARING FOR CRITICALLY ILL NEWBORN FOALS

The birth of a foal is an exciting time, marking the end of a year of anticipation and the beginning of a brand new life. Every horse owner hopes for an uneventful birth and a strong, healthy foal that will thrive and grow into a robust horse. But roughly 3 to 7 percent of newborn foals have some kind of significant health issue in the first month of life and need intensive care to survive.

As human and veterinary medicine have become more intertwined, newborn foals with health problems have benefited from advances made in the care of human infants. Attesting to this are the number of equine neonatal intensive care units (NICUs) that have sprung up around the country since the first one was founded at the University of Florida in 1982.

A sick foal is a challenging patient. Its immune system is still naïve, putting the foal at high risk for infection, and its blood chemistry can vary wildly. Premature or sick foals often lack minimal energy supplies, increasing the risk for hypoglycemia, hypothermia and organ dysfunction.

Like human infants, foals differ physiologically from their adult counterparts and require specialized treatment based on an understanding of their unique physiology. As foals undergo a number of transitions from life in the uterus to birth, complex behavioral, metabolic, cardiopulmonary, endocrine, hematological and other systems changes occur. Peter Rosedale,



a British veterinary surgeon who developed a keen interest in equine neonatology early in his career, was the first to detail these types of changes in normal Thoroughbred foals in the 1960s. His main research interests related to late gestation and maladjustment conditions of the newborn foal. [In neonatal maladjustment syndrome, the foal displays signs ranging from a slow suckle response, aimless wandering, loss of muscle tone, weakness and seizures. Also known as “dummy foal syndrome.”] Dr. Rossdale developed a model of equine prematurity and studied the adaptive responses of the newborn. Since then, many researchers around the world have added important information about neonatal foals that clinicians today can use in their evaluations.

UC Davis has a long history of veterinarians who have helped pave the way for treating critically ill foals. Gary Magdesian, a veterinarian in critical care and emergency medicine and neonatology, has combined his specialties to head the NICU at UC Davis. His foundational studies have provided new knowledge about body fluid content in foals, including their total, intracellular and extracellular water compartments; regulating blood glucose in foals; understanding the role of *Clostridium difficile* in foal diarrhea; establishing safe and effective dosage levels of antibiotics; and tracking congenital heart defects, to name a few. Other veterinarians like Bill Thomas, former chief of cardiology at the Veterinary Medical Teaching Hospital, and John Madigan, a professor of equine medicine, examined cardiopulmonary changes in the foal at birth and in the neonatal period.

Monica Aleman, one of the few board-certified veterinary neurologists working in the



A foal patient greets Dr. Monica Aleman. Photo by Joe Proudman, UC Davis.

clinical neonatal area, has performed studies on the normal ultrasound anatomy of the foal. She has also conducted studies on brain function in neonates, including brain wave studies in maladjusted foals, and electrophysiology research, which produced the first clinical method of diagnosing botulism in foals. Dr. Aleman recently documented that many sick foals suffering from conditions other than neonatal maladjustment syndrome have significantly elevated neurosteroid levels—a finding that now changes the approach to field treatment of weak or disoriented foals.



Dr. John Madigan examines a foal with neonatal maladjustment syndrome as the dam looks on. *Photo by Joe Proudman, UC Davis.*

David Wilson, director of the Veterinary Medical Teaching Hospital, has contributed a great deal in the areas of pharmacology and to our knowledge of effective antibiotics in septic foals. Nicola Pusterla, professor of equine medicine, has studied molecular markers of sepsis and the pharmacology of ceftiofur, an antibiotic, in foals.

John Madigan, whose decade-long study of neonatal maladjustment syndrome (dummy foal syndrome) resulted in a breakthrough that made headlines recently, was instrumental in establishing one of the early equine NICUs in the country. The NICU at the UC Davis Veterinary Medical Teaching Hospital was established in 1987 and, like other pioneering NICUs around the country, acquired expertise by treating sick foals and working with



neonatologists in human medicine. Boyd Goetzman, then chief of the division of neonatology at the UC Davis Medical Center, was a mentor to Dr. Madigan, coming to rounds every week and consulting on individual cases. Together, Dr. Madigan and Dr. Goetzman ventilated the first foal ever, using surfactant commonly used for premature human infants. The foal survived.

A number of conditions can place a newborn foal in jeopardy:

- **Sepsis**—a state of both infection and a systemic inflammatory response. *It is the major cause of death in foals less than 7 days old* and is a common complication of other neonatal conditions such as prematurity or neonatal maladjustment.

Different degrees of sepsis can include complications of organ dysfunction and circulatory failure.

- **Failure of passive transfer** (transfer of antibodies from the mare to the foal via colostrum)
- **Diarrhea**
- **Neonatal maladjustment syndrome**
- **Hypoxic injury** (oxygen deprivation in foals born from a difficult birth or with a congenital abnormality)
- **Colic**

- **Prematurity/dysmaturity** (dysmaturity is the lack of development in a foal that has a normal gestation period)
- **Respiratory distress/pneumonia**
- **Ruptured bladder**

When a weak or recumbent foal on a farm is evaluated by a veterinarian, it can be difficult to make a definitive diagnosis because many of the above conditions can cause weakness. Consequently, the approach might be to treat what is treatable and prevent what is preventable. In many cases, the goal will be to stabilize the foal before referral to a NICU where more intensive and continuous treatment can be provided.

Sick foals decline rapidly, so aggressive early intervention is a key factor for survival.

Many foals have been treated successfully in a field setting using techniques developed in the NICU, such as intravenous fluid therapy and nutritional support, medications, milk feeding via nasogastric tube, and prevention of sepsis with antimicrobials. While this is a positive advancement, caring for a sick foal is labor-intensive, requires excellent collaboration between veterinarian and horse owner, and is stressful for the owner/caregiver.

For other sick foals—for example, foals that are premature/dysmature, septic, or in respiratory distress—referral to a NICU or hospital is necessary for survival. Again, the key is to get these fragile foals in quickly. In some cases, referral is not an option for financial or prognostic reasons. This is a personal decision to be made between the horse owner and veterinarian.

A Story of Hope for Amal

In the past, a premature foal (born less than 320 days of gestation; normal gestation period is 320 to 360 days) was regarded as a lost cause with little chance of survival and even less hope of being an athletic adult. Today, prematurity is no longer a death sentence or an automatic label of *nonathlete*, thanks to equine NICUs around the country and accumulated wisdom.

For Helen McCloskey, owner of a premature foal, neonatologists at UC Davis gave her the gift of life. With over 35 years of caring for critically ill foals, the UC Davis team pushed the boundaries of neonatal medicine and accomplished what was in the not-so-distant past impossible.

The foal, named Amal, was born approximately three weeks premature and weighed just 31 pounds when brought to the NICU at the William R. Pritchard Veterinary Medical Teaching Hospital at UC Davis. A healthy average foal weighs 70-100 pounds at birth. In addition to being premature, she also had evidence of intrauterine growth restriction, meaning her development was much slower than normal because of abnormal placentation. She was not ready to be born. This combination of prematurity and intrauterine growth restriction made Amal very small and underdeveloped. She also had inadequate bone formation in her knees and hocks, since complete ossification in foals *in utero* does not occur until the last weeks of development.

As Gary Magdesian, chief of equine neonatology and critical care, explained: “Amal’s management was divided into short- and long-term approaches. The short-term interventions



included enteral nutrition through a feeding tube, antibiotics, enemas, a urinary catheter, IV fluids to stabilize her blood pressure, and oxygen insufflation into her lungs to help her breathe. The more difficult challenge was to ensure Amal's long-term survival."

Some of the long-term problems she presented were a lack of bone formation in her knees/hocks due to her prematurity, juvenile Arabian epilepsy, and a swallowing disorder (temporary pharyngeal paresis). Special care was required to prevent her from standing, which could cause permanent damage to her legs. As a result, she was mostly recumbent for one month. Many students and veterinary technicians provided round-the-clock care for Amal.

Amal's owner Helen recalls her experience:

I decided to give a green light to try to bring this tiny girl forward because I wanted, and naively hoped, that the bond between mare and foal might be maintained and that if the



In the Neonatal Intensive Care Unit at the Veterinary Medical Teaching Hospital, Amal receives treatment as her dam, India, watches nearby.



Dr. Gary Magdesian attending to Amal in the NICU.

filly could get to the point of being able to stand and nurse, the mare could resume her mothering—something she clearly wanted to do. She was going to be milked and kept next to the filly in the NICU, so this seemed a possibility. Also, it was my intuitive impression that the filly herself had a strong will to live, something that proved to be true.

Another reason I decided to give the green light to try to save the filly was that I have taken my many animals to UC Davis for the past 20-plus years, and I have great respect for the veterinary school. This was to be my last breeding, and so I went for it, as much for the mare as for the filly, but also with the appreciation of the fact that a teaching hospital moves forward with challenging cases.

The care Amal received from Dr. Gary Magdesian and his staff was nothing short of phenomenal. There was as much heart and affection involved with her long journey as there was science. For me, the anxious client, the “bedside manner” of most of her attending vets as well as her main vet, was a very important factor in enduring the ups and downs of the journey.

I hope that Amal did move the science and art of neonatal care forward in some small way. I know she has touched many hearts and I received very kind words along the way, including a note from one veterinary student who said that as a result of her



Helen McCloskey with Amal in April 2015.



Horse trainer Robert Gonzales has worked with Amal since early this year to teach her some foundational skills.

involvement in Amal's care, she had reconsidered her direction in veterinary medicine. That meant a lot.

Amal is an athletic, enthusiastic, smart youngster. It was a great joy when she came home to me in September, though she still required a considerable amount of special care. She has challenges like a seizure disorder, which she has almost outgrown, but her future looks bright, thanks to the state-of-the-art equipment, care, and the many extraordinary students, staff, and veterinarians at UC Davis, particularly Amal's human godfather, Dr. Gary Magdesian.

Fast forward to January 2015. At the age of 8 months, Amal began working with trainer Robert Gonzales of Ione, California, to learn some basic skills such as haltering, leading, respect for personal space, and socialization. Because of her former fragile state, Amal was essentially raised as an orphan and did not benefit from the important socialization learned from the mare. She proved a quick study and clearly enjoyed learning and interacting. Today, she is continuing her training with Robert and has another CEH yearling to keep her company and aid in her socialization. After a challenging start in life, Amal—pictured on the cover—is a healthy, happy yearling.



Earlier this year, Amal met other weanlings at the CEH. Because of her fragile start in life, she had not had much exposure to other horses. As the photo shows, there was much mutual interest between the horses and Amal.



A new foal sits sternal (on his chest/belly) with head held up within moments of birth.

The Healthy Foal

One of the keys to identifying a problem in a newborn foal is to understand what a normal foal looks like. A new foal sits sternal (on his chest/belly) with head held up within moments of birth. The foal will shake its head, lick its lips and will often start to vocalize when it sees and hears its mother. It is attached to the umbilical cord until the mother stands, at which point the cord breaks at an ideal distance from the body wall, with minimal bleeding. Most healthy

foals will stand within 1 hour, nurse within 2 hours, and show great affinity for its mother and a strong urge to suckle.

The foal will initially display jerky, uncoordinated movement that improves with each passing hour. The consumption of antibody-rich colostrum is vital to closing and protecting the newborn gut, conferring normal immunity and providing the much needed nutrients and hydration (i.e., energy) for continued activity.

Consumption of milk is verified by audible swallowing and the baby will nurse briefly several times per hour, with periods of sleep between feedings. Most foals will urinate within hours of foaling (average of 6 hours for colts and 10 hours for fillies) and the onset of nursing will stimulate the first stool production, known as the passage of meconium, within an hour of

birth. This initial manure is dark in color and turns a light tan once mare's milk has been digested and meconium has completely passed (often within 12 to 24 hours). The foal's legs may appear slightly lax or contracted initially, but this should improve over 24 to 48 hours. With each passing day, the foal will gain weight and look less ribby.

A neonatal foal/mare exam is recommended at 10 to 12 hours of birth, as long as all the timelines above are met. More immediate intervention is warranted if the foal fails to stand or nurse within the first few hours, if it is not active or nursing frequently, or if it is considered to be at risk for complications from abnormalities in the pregnancy or during the delivery. At the 12-hour exam, your veterinarian will assess the mare to ensure that her vital signs and color are good and inspect her perineum to identify trauma or need for medical or surgical treatment. The placenta will be inspected for its weight (not greater than 10% of foal body weight) and to ensure that it was passed completely. Normal expulsion occurs as the third stage of labor, and the placenta is considered retained 3 hours postpartum. Retention of the placenta for longer than 3 hours should be considered an emergency. The mare's mammary development will also be noted.

The veterinarian will then turn his or her attention to the foal. Mares can be very protective of foals, and judicious use of halter and restraint by an experienced handler is recommended. Initial assessment of respiratory rate and heart rate can be done before any foal handling if the foal is resting. This minimizes the effect of excitement on the vitals. The foal will often stand once the rectal temperature is taken and will require gentle restraint for the rest of the

**VIDEO: Dr. Gary Magdesian
Demonstrates a New Foal Exam**





exam. Again, proper restraint of the mare during this exam is crucial and a team of veterinarian, mare handler and foal handler is ideal to safely and accurately accomplish the post-foaling exam. To learn more about the elements of a new foal exam, please watch the video.

Reasons to Call the Veterinarian

Foals are very different from adult horses in their susceptibility to disease and in their resilience. The neonatal period is the riskiest time in the life of

a horse. Hours can make the difference between life and death, so prompt action is crucial. Some foals may be normal at birth and then start to display behavior that requires veterinary intervention. This is why it is important to carefully observe any new foal in the first few weeks of life.

Call your veterinarian if you observe:

Prematurity/Dysmaturity. The normal gestation period for foals is 320 to 360 days. A foal is considered premature if its gestational age is less than 320 days. Note, however, that every mare has her own “normal” gestational length and that they tend to be fairly consistent from year to year. In other words, 320 days may be normal for one mare but very premature for another. Dysmaturity means immature development in spite of normal gestational age, so foals that are dysmature exhibit signs of prematurity after a normal gestation period. Signs may include:

- Small size, floppy ears, domed forehead, flaccid lips, silky haircoat, and sometimes slipper-like hooves. Lack of hair indicates a gestation period of less than 270 days except in cases of abnormal placentation, where the fetus was restricted by the uterus or in cases of twins.
- Incomplete ossification (lack of bone development) of the small cuboidal bones of the carpi (front knee) and hocks, and tendon/ligament laxity.
- Abnormal white blood cell parameters identified on a complete blood count.
- Dysphagia or temporary loss of coordination of swallowing muscles. This manifests as milk dripping from nostrils or mouth and puts the foal at risk for aspiration pneumonia.
- Premature/dysmature foals require advanced support and referral if they are unable to stand or nurse. Amal (foal on the front cover) was one such foal who defied the odds.

Decreased activity and nursing. This is often the first sign of a problem. Spending increasing time laying down or asleep should raise concern. The mare's udder will be more pendulous than normal or even drip milk. This can progress to lack of suckle reflex or attachment to the mare.

Fever. Any change in behavior warrants obtaining a rectal temperature. Any temperature over 102 degrees or under 99 degrees in a depressed foal requires immediate communication with your veterinarian. However, **only about 50% of foals with infections have fevers, so lack of a fever does not rule out infection.**

Seizures. Mild seizure activity in a foal can be as subtle as staring off into the distance with excessive blinking. Grand mal seizures often involve a loss of consciousness and large-scale tremoring in lateral recumbency. Causes of seizures can vary from infection to brain

hypoxemia (lack of oxygen to the brain), from metabolic disturbances such as low calcium or glucose to genetic disorders. Immediate veterinary intervention is warranted.

Diarrhea or colic in neonates is worrisome and immediate veterinary involvement is advised. Diarrhea puts the foal at risk for dehydration and can be caused by infectious agents, parasites, consumption of sand, overeating, lactose intolerance, or intestinal abnormalities. Supportive therapy and fluid administration is often required

and failure to respond warrants referral. Mild diarrhea at one to two weeks of age in a foal with normal behavior and nursing activity, also known as foal heat diarrhea, is an exception to this rule. Note that “foal heat diarrhea” has nothing to do with the mare’s first heat cycle but rather is due to maturation of the gut. Normal foal manure is semiformed and is not similar in appearance to adult horse manure.

Common causes of neonatal colic include: meconium impaction, viral or bacterial infection (infection type varies with age of foal), overfeeding, ruptured bladder (abdominal pain), gastric ulceration, and parasitism.

Lameness or swollen joints require immediate examination. Never assume the mare stepped on the foal. Neonatal lameness is often associated with sepsis and spread of infection



Mild diarrhea at one to two weeks of age in a foal with normal behavior and nursing activity, also known as foal heat diarrhea, is not necessarily a sign of illness.

to the joint or growth plate, often within the first 30 days of life. Common sources of infection include the gut, umbilicus, lungs, and occasionally penetrating wounds. Time is of the essence in these cases and prognosis declines rapidly if not treated in the first 24 hours of symptoms. Referral to a NICU is recommended.

Labored respiration in the foal is a cause for concern. Any issue that impairs oxygen delivery can cause an increased rate or effort. Pneumonia can occur with septicemia and can be subtle in the foal. Foals often fail to cough or display abnormal lung sounds and often do not have any nasal discharge. Bacterial or viral infections will vary based on age of the foal. Laboratory work and imaging are necessary to diagnose pneumonia and much of this can be accomplished in the field. A respiratory rate less than 20 or greater than 60 can be a significant cause for concern, and these foals often require oxygen supplementation in the NICU if the rapid respiratory rate is associated with respiratory abnormalities.

Abnormal mucous membrane color (yellow or grey) can indicate an underlying problem and warrant immediate investigation. Some mares develop antibodies to the red blood cells of their foals and these foals develop a condition known as NI (neonatal isoerythrolysis). The colostrum they consume contains antibodies which destroy their own red blood cells and causes icterus—a yellow discoloration of the mucous membranes. This condition often develops at 3 to 5 days of age and can be treated successfully in the field if identified early. It is also easily prevented by testing of the dam's blood during the last 4 weeks of pregnancy.

Milk dripping from the nostrils of a foal can indicate a neurologic issue or a functional abnormality of the pharynx. Foals with this issue are at risk for pneumonia, and further investigation is warranted.

Straining to urinate or defecate is not normal in the foal. Meconium impaction is the most common reason for straining or flagging of the tail. This occurs in the first day or two of



Occasionally, foals can have significant internal umbilical infections with no obvious external signs.

life and is often successfully managed in the field with diagnostic imaging and enema and fluid administration. Straining to urinate can be indicative of a ruptured bladder in the foal. Colts are more likely than fillies to be affected and these foals will often show progressive depression and a distended abdomen. Foals with ruptured bladders require referral to a NICU for medical and surgical management and have a good prognosis if not septic.

Swollen, cloudy or weeping eye

requires immediate veterinary attention. Common foal issues include corneal ulceration from shavings or stall trauma, entropion (folding of the lid into the cornea), or more seriously, uveitis. Uveitis in a newborn can indicate sepsis and carries a poor prognosis.

Swollen or moist umbilicus. The umbilicus is the second most likely route of entry for infectious agents in the foal, after the gut. Swelling or moisture warrant immediate investigation and can be indicative of infection or a patent urachus. The urachus is the umbilical remnant that carried fetal waste from the foal's bladder to the outer placental sack. This structure can become torn or infected and pose a risk to the foal. The umbilicus can be imaged ultrasonographically in the field and most umbilical infections respond well to aggressive antibiotic therapy. Some umbilical conditions require referral and surgical removal. Occasionally, foals can have significant internal umbilical infections with no external signs.

Factors that Warrant Immediate Referral to a NICU

- The foal does not have a suckle reflex and does not have normal gut motility to digest milk placed in the stomach via nasogastric tube.
- Foal that requires oxygen administration, and heart rate and respiratory rate are not stable.
- Foal is unable to stand unassisted. This can be due to weakness or to abnormal limb development.
- Foal is notably premature or dysmature (immature development in spite of normal gestational age).
- Foal cannot maintain normal body temperature (indicative of compromised circulation or maladjustment).
- Foal is not responding to supportive therapy in the field and remains depressed and weak.
- Unresolving diarrhea or colic.

A NICU will be able to provide specialized equipment and expertise that a critically ill foal needs, including:

- A controlled environment with minimal pathogens and ideal temperature, often with accommodations for mare nearby.
- Continuous care and observation by trained personnel.





Dr. John Madigan inspects a maladjusted foal. *Photo by Joe Proudman, UC Davis.*

- Continuous and monitored intravenous fluid and medication administration.
- Parenteral (intravenous) nutrition administration for foals with a dysfunctional gut.
- Immediate access to laboratory measurements (blood work) which are used to direct supportive therapy; often performed two to three times daily or more, depending on how critical the foal is.

- Access to advanced imaging such as ultrasound, radiology and CT.
- Support and physical therapy for recumbent foals.
- Access to surgical and anesthesiology teams with neonatal experience.

NICU Techniques Applied in a Field Setting

Lessons from the NICU have given veterinarians some tools that can be used in the field to treat mild problems. These include initial assessment tools, thermoregulation efforts, nasal oxygen therapy, IV fluid resuscitation, glucose administration to foals that aren't nursing, and prompt medical therapy for infection. If the foal fails to improve with initial supportive care in the field, then prompt referral to a NICU is essential for survival.

The most common cause of weakness and inability to rise is birth asphyxia, maladjustment and sepsis (systemic infection). Your veterinarian will take blood samples for testing and may start appropriate antibiotic therapy based on research of susceptibility to common pathogens of neonatal foals. Because foals process medications differently from adult horses, dosages should be adjusted for the foal (*Manual of Equine Neonatal Medicine*, 2013). If the foal fails to respond to initial treatment and is unable to rise or nurse on its own, referral to a NICU is warranted. Survival rates go down dramatically with delay in referral in these cases.

Measurement of a foal's antibody level as indicated by blood IgG (immunoglobulin G) is a critical component to ascertaining health and risk for illness, particularly since a foal may not show signs of infection in the early stages of sepsis. A stall-side kit is available to analyze a small amount of blood taken from the jugular vein. The antibody level should be greater than 800 mg/dl in a healthy foal that has consumed enough good-quality colostrum by 12 to 18 hours of age. Foals with lower IgG levels should be managed carefully to minimize chances of infection. Failure of passive transfer or low IgG levels puts the foal at significant risk for



infection and is time-sensitive. [NOTE: Even if a foal has an IgG of 800 mg/dl, if it is in a dirty environment, it is still considered at risk for sepsis. The degree of protection from colostrum and IgG depends on the *balance of bacterial exposure factors and degree of immune response.*]

In addition to antibiotic therapy, weak foals often require IV fluid administration, usually with supplemental glucose for energy. New research suggests that carefully calculated fluid doses are very effective at treating mild, initial dehydration. Foals who fail to respond to such support or who require continuous IV fluid therapy should be referred to a NICU.

Insufficient oxygenation (lack of oxygen to the heart, lungs and circulatory system) is another problem in the field that can render a foal weak and affect their behavior and affinity for the mare. Low oxygen or hypoxia can occur during gestation if the placenta is functioning poorly, is infected, or is too small to support the developing fetus. It can occur during birth if the umbilical cord is compressed, if the delivery is prolonged by dystocia or abnormal fetal position, or if the placenta separates prematurely from the uterus, producing a *red bag delivery*. [Normally, the placenta stays attached to the mare's uterus until the foal is delivered and can breathe on its own. When the placenta separates prematurely, the foal loses its placental blood supply and hence oxygen before it is able to breathe. A red bag delivery is an emergency, and staff must be present who know how to deliver the foal rapidly because it is going through the birth canal with no oxygen.] Mildly affected foals can be managed in the field if they are able to get up and nurse and stay adequately hydrated, but they should be protected with antibiotics because they are at increased risk of developing sepsis. Otherwise, they should be referred to a NICU for more intensive care.

Hypoxia can occur after birth if the foal's cardiovascular system is impaired by infection or by heart/lung abnormalities. Foals struggling with oxygen issues will often fail their timeline

INTENSIVE CARE FOR FOALS AT UC DAVIS

Sick newborn foals are very critical and, if not treated early, can have severe complications and high mortality. The NICU at UC Davis is staffed by a team with expertise in successfully handling post-birth complications requiring high-level intensive care. Specialized technicians help provide 24/7 monitoring and care, including oxygen, IV fluids, IV antibiotics, and nutritional support.

The NICU is equipped with customized stalls to support sick foals, allowing intensive management under the watchful eye of the mare in an adjoining stall. There are three mare/foal stalls, with ample overflow space into the nearby ICU barn.

The following veterinarians, including a board-certified critical-care specialist and a neurologist, work together to ensure the best possible care for sick foals:

Neonatology/Critical Care

Gary Magdesian, DVM, DACVIM, DACVECC, DACVCP, Section Head

John Madigan, DVM, MS, DACVIM, DACAW

Nicola Pusterla, DVM, PhD, DACVIM

Monica Aleman, MVZ, DACVIM (Internal Medicine, Neurology)

Tania Kozikowski, DVM, DACVIM

Krista Estell, DVM, DACVIM

Carrie Finno, DVM, PhD, DACVIM

For more information on intensive care for foals at UC Davis, please contact the Large Animal Clinic at (530)752-0290.





Over the last decade, we have seen a number of advances in equine neonatal medicine, but there is a continuing need for research to improve our ability to treat critically ill neonatal foals.

for standing and nursing and warrant immediate intervention. It makes good sense to involve your veterinarian early on in any dystocia (difficult birth) or red bag delivery. Delivery of oxygen to a foal via a face mask is possible in a field setting, but prolonged oxygen therapy requires careful monitoring by the veterinarian. If the foal fails to respond appropriately, it should be referred immediately to a NICU.

Advances Made in Neonatal Critical Care

Over the last decade, we have seen a number of advances in critical care medicine for foals. We have increased our understanding of fluid physiology and balance, which allows veterinarians to fine-tune fluid therapy and monitor changes over time in response to treatment. The ability to adjust serum electrolytes and blood sugar (glucose) levels, for example, allows veterinarians to immediately respond to foals in crisis. This has had a significant positive impact on the survival of sick foals.

Antibiotic treatment has been improved. Through pharmacology studies in foals, we have a better understanding of how foals metabolize and eliminate antibiotics, allowing us to administer

more effective drugs in more appropriate dosages. Studies have provided new dose protocols for life-saving antibiotics such as amikacin and ceftiofur. In a study of the widely used antibiotic metronidazole in foals, we found that foals do not eliminate the compound like adult horses; therefore, they need lower doses or longer dosing intervals. We now have newer drugs with different, safer mechanisms of action, allowing treatment of septic foals via continuous rate infusion, which keeps antibiotic levels safely high with good outcomes.

We are better able to monitor cardiovascular status to understand how well blood vessels and the heart are functioning in foals. In addition to ECGs, monitoring equipment has been borrowed from human medicine to measure oxygen saturation, blood pressure, and end-tidal carbon dioxide. This capability allows us to monitor how nutrients and oxygen are being provided to tissues, as well as how well waste products are being eliminated. Because the heart and blood vessels don't function as well in sick foals, we are able to provide fluids and medications that increase heart muscle contraction and blood vessel tone and thereby increase blood pressure to deliver more oxygen to tissues.

We can now provide new modes of mechanical ventilation to foals that have respiratory failure and cannot breathe on their own. The mechanical ventilators are those used for human neonatal medicine and have very modern capabilities.

Because foals are a precocious species, they need to get up and move around. We have learned better ways to manage angular limb problems, including valgus (knock-kneed) and varus (bow-legged) deformities; flexoral limb deformities, including contracture (over at the knee) and laxity (down in the fetlock); and under-developed bones in premature foals. We have made significant advances in treating these conditions, including the use of orthopedic shoes, trimming, physical therapy techniques, and controlled exercise programs that have been adapted from humans and small animals.



DISCOVERIES IN NEONATOLOGY MADE AT UC DAVIS

- Nonsurgical treatment for severe meconium retention syndrome with acetylcysteine enema
- Plasma prevention of *Rhodococcus equi*
- First use of granulocyte colony stimulating factor
- Development of proper dosing for medications used in foals: Ceftiofur, Amikacin, Metronidazole
- Establishment of plasma, red blood cell, total blood, and extracellular fluid volumes in healthy foals
- Establishment of normal values for cardiopulmonary changes post birth
- Investigating the role of vasopressin in critically ill foals
- Creation of constant infusion protocols for intravenous treatments of antibiotics, parenteral nutrition, and specific IV fluids
- Umbilical disinfection use with chlorhexidine
- Post birth prevention of *Salmonella* infection
- Studies of neonatal isoerythrolysis
- Normal ultrasound of the foal chest, abdomen
- First triplet foals ever treated in intensive care
- First treatment to rapidly reverse maladjusted foals
- First colloid fluid therapy research
- First botulism electrophysiological diagnosis
- Studies of bacterial susceptibility of agents causing septicemia
- Evaluation of blood culture systems for detecting septicemia
- Studies of newborn foal diarrhea
- Studies of protozoal transmission during pregnancy
- Creation of molecular diagnostics (real-time PCR) for detecting pathogens in foals
- First successful treatment of a confirmed case of Tyzzer's disease in foals



Triplets are extremely rare in horses, about 1 in 300,000 single births. These triplets and their dam were referred to the UC Davis VMTH in 1986. They were born at approximately 300 days gestation.

There is a continuing need for more research to improve our ability to treat critically ill foals. Some important areas of study are described below.

Areas of Needed Research

Pharmacology. We need to learn more about differences in drug efficacy in foals, including how medications are metabolized and eliminated. Center for Equine Health-funded research in this area provided valuable information on metronidazole, an important antibiotic for newborn foals with diarrhea from *Clostridium difficile*. Antibiotics are a critical area because foals are so vulnerable to infection. Current thinking is to start at-risk foals on antibiotics *before* any signs of infection are evident. At-risk foals generally have conditions that are associated with delayed nursing and gut closure, such as neonatal maladjustment syndrome, prematurity, dystocia (difficult birth), musculoskeletal problems, weak at birth, twins, or delivery in a contaminated environment.

The achievement of optimal levels of antibiotics is an equally important area of study because physiological changes occur during sepsis that affect delivery of antibiotics to tissues, such as low blood pressure. There is no one correct antibiotic dose because the level achieved will vary depending on many host factors and on pathogen characteristics.

Infectious Disease. Because foals are susceptible to infectious disease, this is a critical area of needed research. Both prevention and treatment of infections such as septicemia and enteritis require further investigations.

Neonatal Maladjustment Syndrome (Dummy Foal Syndrome). Building on Dr. Madigan's work with neonatal maladjustment syndrome (NMS), initial observations and hypotheses about NMS need to be scientifically tested and validated. The Center for Equine Health has recently funded a clinical trial that will allow researchers to better correlate



neurosteroid levels and NMS and assess how these levels change in response to squeeze, which mimics the natural birth process. Less time in the birth canal may inhibit a natural process.

There have been parallel applications in humans in the concept of “Kangaroo Care,” in which premature human infants are held against the mother with skin-to-skin contact for several hours a day. The benefits of this kangaroo care have resulted in a precipitous drop in premature infant deaths and include the benefits of stabilized heart rate, more regular breathing, improved oxygen saturation levels, and more.

Sepsis Score. This risk-scoring scheme for neonatal infection needs further validation as it currently has 74% sensitivity in predicting bacteremia. Further research is needed to identify a rapid, field-side test that is sensitive enough to detect infection in foals that have minimal clinical signs, early in the disease process, and specific enough to differentiate between infection and inflammation.

Neonatal Critical Care. Finally, the area of neonatal critical care in general is in need of research to further improve our management of these very sick newborns. ■



WHAT YOU CAN DO TO PROMOTE A HEALTHY FOAL

Many conditions and complications related to foaling are not within your control, but horse owners and breeders can take steps to promote the health of a foal even before it is born. Providing a clean foaling environment and keeping the mare healthy, clean and current on vaccinations are some ways.

Prenatal Care for the Mare. Provide adequate nutrition for the mare, including vitamin E and selenium supplementation to ensure healthy placental function and blood supply to the developing foal. Consult your veterinarian to determine the appropriate dose of supplements. Selenium intake can depend on geographic location.

Ensure that your mare is current with vaccinations as this can positively affect the quality of colostrum.

Ensuring a Healthy Foaling Environment. Bacteria encountered by the newborn foal in a dirty, poorly ventilated stall can easily override the antibodies received from the mare's colostrum, even if the foal's IgG is at or above the desired level of 800 mg/dl. In nature, a mare will wander off to a site of her choosing that is free of manure. The ground is baked by the sun, which minimizes pathogen levels. On a farm, it is a different situation.

Before placing the mare in the stall, inspect the stall and eliminate hazards such as raised nails, large splinters and water buckets. High-quality, dust-free straw is the preferred bedding; wood shavings can be inhaled by the newborn foal. Foals maintained on straw for the first three weeks of life have been shown to be less likely to develop umbilical infections.

Disinfect the stall before foaling:

1. Remove all bedding.
2. Remove all non-permanent objects, such as buckets and feeders. Using a mixture of hot water and dish detergent, scrub them free of residue. Rinse thoroughly, then scrub again with a solution of 1 part laundry-type chlorine bleach to 10 parts water. Allow them to air dry without rinsing. Scrub one more time with hot water and dish detergent. Rinse thoroughly to remove any bleach or detergent residue.
3. Sweep cobwebs, dust, hay, and other debris from the stall floor, walls, ledges and door.
4. Wash walls and other solid surfaces using a pressure washer (or garden hose), a stiff scrub brush and dishwashing detergent.
5. Mix Lysol Disinfectant Concentrate (2-1/2 tablespoons per gallon of water) in a garden-type spray tank. Wear protective



clothing, including long sleeves, long pants, gloves, goggles and head gear. Spray a soaking mist of disinfectant onto all surfaces and allow to air-dry. Repeat.

6. Return clean buckets and feeder to your horse's stall. Bed with clean straw.

In addition to a clean stall, a clean mare will help prevent the foal from ingesting bacteria from nursing or other contact with the mare. In preparation for foaling, excess dirt and debris should be washed from the mammary glands and perineal area. Tail hair may lacerate the foal, and is difficult to keep clean unless controlled, either by clipping or by tail wraps. If tail wraps are used, they should be cleaned and changed daily, and not too tight around the base of the tail.

Once the mare has foaled, gently wash her perineum and udder with Ivory soap and warm water. Rinse and blot dry. This can be done while the foal is sternal in the stall.

Remove the placenta and fetal fluids as well as any manure from the foaling stall and refresh with clean straw. Maintain a muck bucket and fork just outside the foaling stall and pick the stall throughout the day.

Caring for the Foal. Have a Playtex nurser bottle or lamb nipple and bottle handy and a clean stainless-steel receptacle to milk out the mare and start supplementation if nursing is delayed and a strong suckle response is present. **Never force feed or syringe a foal that does not suckle as the foal can aspirate the milk and develop pneumonia.** The bottle should be offered at head height, not above. A healthy 90-lb foal can drink 8 ounces of colostrum at a time and needs a minimum of 16 ounces of high-quality colostrum orally to confer immunity in a clean environment. The higher the pathogen load in the environment, the higher the IgG level needs to be for protection.

Newborn foals should be carefully monitored over the first days, even those that appear normal and healthy at birth, as they can develop problems very quickly.

If the foal displays lethargy or excessive sleepiness, a distended abdomen and failure to pass urine within 8 hours, a jaundiced appearance, diarrhea combined with depression, any lameness or limb swelling, or swelling or drainage of the umbilicus, immediate veterinary care should be sought. ■






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CEH HORSE REPORT

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May 2015

The *CEH Horse Report* is published by the School of Veterinary Medicine at the University of California, Davis: Michael D. Lairmore, Dean; Claudia Sonder, Director, Center for Equine Health; Barbara Meierhenry, Senior Editor; Don Preisler, Videographer.

Please send questions or comments to: Editor, *CEH Horse Report*, cehwriter@ucdavis.edu; (530)752-6433.

The Center for Equine Health is supported with funds provided by the State of California Pari-Mutuel Fund and contributions by private donors.

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