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Failure of passive transfer in foals: A review

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Failure of passive transfer is a major predisposing factor for a variety of neonatal infections, including sepsis, the major killer of neonatal foals. This issue of *Large Animal Veterinary Rounds* reviews the different methods of detecting, treating, and preventing the failure of passive transfer.

What is failure of passive transfer?

Failure of passive transfer (FPT) occurs in newborn foals; it is defined as an inadequate transfer of colostral immunoglobulin from the mare to the foal or as an inadequate absorption of immunoglobulin (Ig) by the foal.¹ FPT is thought to be the most important predisposing cause for infections and death in foals.²

Except for minimal transplacental transfer of IgM, the diffuse epitheliochorial placenta in the mare is impermeable to the passage of immunoglobulins from the mare's bloodstream to the foal.¹ Therefore, the newborn foal is hypogammaglobulinemic and dependent on the passive transfer of Ig in the colostrum to provide protection during the neonatal period. The foal's own primary immune response – first stimulated at birth – takes about 10 to 14 days to fully develop.^{1,3}

Colostrum contains high levels of antibodies (mostly IgG) and is produced by the mare during the last 2 to 4 weeks of gestation. It is replaced by normal milk within 12 hours of the foal's first suckling.¹ A normal foal should receive colostrum within the first 3 hours after birth; antibodies from the mare's colostrum are first detectable in the circulation of a foal by about 6 hours of life and absorption is almost complete within approximately 24 hours. The small intestine of the newborn foal is lined with specialized epithelial cells that are able to absorb colostral Ig by pinocytosis. This ability decreases dramatically after the first 6 to 8 hours of life and, by 24 to 36 hours, a high percentage of the epithelial cells are replaced by mature enterocytes.¹ Maternal Ig has a half-life of 3 weeks; therefore, its concentration in the foal's blood gradually decreases and is almost undetectable by 5 to 6 months of age. By about 4 months of age, however, the foal's autogenous immunoglobulin production allows serum Ig concentrations to reach the levels of an adult horse.³

The development of diseases like sepsis, pneumonia, or diarrhea is likely multifactorial, but FPT is an important predisposing factor in foals. Additional factors (eg, environmental conditions, pathogen load, type of pathogen, stress, or the presence of other diseases) play a role in the development of illness.¹ A retrospective study at a Standardbred farm suggests that foals born earlier in the season, (ie, during the colder months of the year), as well as smaller and less well-developed foals, are at greater risk for FPT.⁴

Causes of FPT

Causes of FPT are variable and may not always be determined in an individual case (Table 1). Some mares drip milk before parturition (premature lactation). This is associated with placentitis, twin pregnancies, or premature placental separation. FPT should be anticipated as a complication



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Lack of colostrum (mare)	Premature lactation Inadequate colostrum production Death of mare
Poor quality colostrum	Inadequate concentration of immunoglobulins
Lack of colostrum intake	Rejection by the mare Prematurity Weakness Congenital defects
Increased use of antibodies	Sepsis
Lack of absorption	Prematurity Weakness due to illness Stress Glucocorticoid administration

when any of these conditions occur.¹ It is also possible that the mare is not able to concentrate enough Ig in the colostrum (normal colostrum IgG content should be >30 g/L) or does not produce enough colostrum. This is a rare problem; mares thought to be at risk are mares >15 years of age, those that foal earlier in the year, and Standardbred mares.³ Failure to concentrate enough Ig in the colostrum has also been associated with serious disease in the mare prior to parturition, as well as with induced parturition. Some mares reject their foals, leading to failure of colostrum ingestion in an otherwise healthy foal. Conversely, some foals are not strong enough to find the udder and suck colostrum due to prematurity, congenital defects (eg, cleft palate, orthopedic abnormalities), or illness (eg, ischemic hypoxic syndrome, injuries). Endogenous (eg, stress) or exogenous factors (eg, glucocorticoids) may cause early maturation of enterocytes and reduce absorption of Ig.^{1,5}

Diagnosis

A serum IgG concentration >8 g/L (800 mg/dL) in the foal is generally considered to indicate an adequate intake of colostrum and, therefore, good protection. A normal foal with optimal colostrum intake, however, should have serum IgG concentrations above 10 to 12 g/L (1000 to 1200 mg/dL). These Ig concentrations are sufficient to protect the foal for the first couple of months of life. Complete failure of passive transfer is defined as serum IgG concentrations <2 g/L (200 mg/dL), while partial failure is defined as a concentration between 2 and 8 g/L (200 and 800 mg/dL). It is important to note that these values apply to foals between 18 and 24 hours old.¹ Blood samples taken before 18 hours of life may show a lower IgG concentration, since Ig is still being absorbed or transported in the lymphatic system and may not be present in the bloodstream.⁶ Early testing of foal serum IgG concentrations, on the other hand, can reduce the need for plasma transfusion

Age (hours)	Minimal recommended IgG concentrations
Early testing (8-12 hours)	2 to 4 g/L (200 to 400 mg/dL)
Late testing (18-24 hours)	> 8 g/L (> 800 mg/dL)

because it would still be possible to supplement with oral colostrum (Table 2). Oral colostrum supplementation is advisable if serum IgG concentration is <4 g/L (400 mg/dL).⁶ Testing between 1 and 8 days of age in healthy foals will result in small changes in Ig concentration from those at 24 hours as some colostrum Ig is lost and *de novo* synthesis commences.

A number of tests are available to measure the IgG concentration in a foal's serum. A recent review concluded that, while a high negative predictive value was particularly important to ensure correct identification of all foals with FPT, many tests would be expected to give false positive predictions of the presence of FPT (Table 3).⁷

Single radial immunodiffusion

Single radial immunodiffusion is probably the most accurate test; however, it is expensive; current price at the University of Saskatchewan's Prairie Diagnostic Laboratory: \$30. (www.usask.ca/pds price list available on webpage), requires submission to a laboratory, and has a turnaround time for results of about 24 hours. It is an accurate and specific quantification of the serum IgG concentration in the foal and can be used for testing colostrum quality. It is also very useful as a reference method to evaluate other commercially-available stall-side tests.²

Enzyme-linked immunosorbent assay (ELISA)

Several tests of this type are available. One of the best known is the foal SNAP[®] test (<http://www.idexx.com/equine/index.jsp>). It provides a semiquantitative measurement of the IgG concentration in equine whole blood, serum, or plasma. It is very easy to use and rapid, with test results available in approximately 15 minutes. Studies comparing the SNAP ELISA with single radial immunodiffusion revealed a high sensitivity and specificity for detecting foals with FPT. Therefore, SNAP is recommended as a good screening test for controlling IgG content in a foal's blood.⁸ More recently, a quantitative immunoassay has become available that gives numerically more accurate results, although the difference is not statistically significant (Table 3).

Zinc sulfate turbidity test

This test measures total Ig (all classes) concentration in serum. Note that the use of plasma can lead to falsely elevated results, since fibrinogen is also measured.⁵ This test

Table 3: Comparison of accuracy of different commercial tests for the detection of FPT⁷

Test	Type	Detection of IgG < 4 g/L			Detection of IgG < 8 g/L	
		Sensitivity, %	Specificity, %	Accuracy, %	Sensitivity, %	Specificity, %
Equi Z, VMRD	Zinc sulfate precipitation	89	78	82	81	57
Gammacheck E, Veterinary Dynamics	Glutaraldehyde coagulation				93	59
Snap, Idexx Laboratories	Semiquantitative Immunoassay	89	93	93	81	95
Midland 4 Quick Test Kit, Midland Bioproducts	Semiquantitative Immunoassay	89	79	81		
Midland 8 Quick Test Kit, Midland Bioproducts	Semiquantitative Immunoassay				52	100
DVM Stat, CAA	Quantitative Immunoassay	100	97	97	98	83

is fast (approximately 1 hour to complete), easy to use, and yields reliable results. The test is based on zinc precipitation of Ig, resulting in turbidity (visible clouding) of the mix. The turbidity can be measured by photometry or assessed visually. Visual assessment is carried out by performing the test on the mare's serum and comparing it to the foal's. Hemolysis can lead to an overestimation of the Ig concentration in the sample.^{2,9}

Another method used by some clinicians is the measurement of total serum protein concentration by refractometry. However, a wide range of total serum protein values in foals before and after suckling, and a wide overlap of these values between colostrum-deprived foals and foals with sufficient colostrum intake, have been demonstrated. Therefore, refractometry is not recommended as a reliable indicator for FPT.⁹ Other less-frequently used tests include the latex agglutination test, glutaraldehyde test, and serum electrophoresis.

In cases where inadequate colostrum quality is suspected, the IgG content of the colostrum can be measured by radial immunodiffusion or a colostrometer. The IgG concentration should be at least 30 g/L (3000 mg/dL); ideally, it should be >70 g/L (7000 mg/dL). The specific gravity of colostrum measured with a colostrometer is directly correlated with its IgG content.¹⁰ A specific gravity of 1.060 reflects an IgG concentration of 30 g/L (3000 mg/dL); the ideal specific gravity would be >1.090.¹ One study compared IgG levels in colostrum measured by immunoturbidimetry with measurements by a refractometer designed for sugar concentrations.¹¹ The study revealed a good correlation between colostrum IgG and refractometer readings. A reading on the refractometer of 30% correlates with a colostrum IgG content of 80 g/L (8000 mg/dL). Good quality colostrum should have a reading of at least 20% (equivalent to 40 g/L) IgG content.

Treatment

Treatment of FPT should start as soon as possible. The ability of the foal to absorb any orally-administered Ig decreases dramatically after it is 6 to 8 hours old, making treatment more complicated and intensive. As a result, the most important management issue is prevention. The serum Ig concentration at which intervention is warranted depends on the age of the foal. The perceived degree of risk to the foal will also influence which cutpoint is chosen (Table 2). If the decision for treatment is made, it is reasonable to choose a treatment approach based on the age of the foal. Foals <12 hours old require different treatments from those >12 hours old.

Foals <12 hours old

If the foal has a good suck reflex, oral supplementation can be attempted. In some cases, the problem may simply be that the foal has failed to suck from a nervous mare or one in pain (udder edema). These foals can be treated by sedating or restraining the mare, milking her out to reduce any discomfort from a swollen gland, and assisting the foal to find a teat. Sometimes, it may be beneficial to feed the colostrum from a bottle. Typically, a sawed off 60 mL syringe with an inverted plunger is used to collect colostrum (Figure 1). A lamb nipple can be used for feeding. If the foal is reluctant to drink from the mare or a bottle, possibly because it is a "dummy foal," a stomach tube can be employed. Ideally, equine colostrum is administered (see prevention section below regarding collection and storage). The quantity administered depends on the size of the foal. The recommended amount for a 40 to 50 kg foal is 1 to 2 L in 500 mL feedings, 1 hour apart, as soon as possible after birth. Even with 30 g/L IgG content in the colostrum, this provides the foal with about 1g/kg IgG, which is the recommended dose to raise its IgG levels to

Figure 1: A 60 mL syringe converted into a device to milk colostrum from a mare's udder



Image courtesy of Dr. Jonathan M. Naylor

>4 g/L.^{1,3} An important thing to remember is that if the foal is already suffering from sepsis, it needs more IgG than a healthy foal because antibodies will be utilized more rapidly.

Other options for oral supplementation are lyophilized IgG products:

- HiGAMM EQUI[®] (www.lakeimmunogenics.com)
- Seramune Equine IgG[®] (www.seramune.com)

These can be given orally, as well as intravenously.¹²⁻¹⁴

In emergencies, if intravenous administration is not possible, equine plasma can be given orally. However, it is an inefficient use of plasma and very large volumes may be needed (2-4 L) to sufficiently raise the serum IgG concentration of the foal.³

Bovine colostrum has been discussed as a possible replacement for equine colostrum.¹⁵ However, bovine IgG has a very short half-life in foals, approximately 7 to 8 days, and is not specifically directed against equine antigens. Regardless of which oral supplement is used, the foal's serum IgG concentration should be measured after 24 hours of age to ensure adequate transfer.

Foals >12 hours old

In foals older than 12 hours, parenteral treatment is recommended because the point of maximal absorption through special epithelial cells has passed and it is difficult to predict how much of the orally administered colostrum or Ig will be absorbed. Equine plasma or serum products (see above or www.veterinarydynamics.com) from horses immunized against common equine pathogens, are commercially available for intravenous administration.^{1,3} They contain a known high concentration of IgG and are free of alloantibodies and infectious agents. However, they may not contain enough specific antibodies for the foal's present environment. Nevertheless, they are a convenient alternative to producing plasma.¹

The easiest way to obtain plasma is to draw blood from a healthy, recently (4 to 6 weeks) vaccinated horse

on the same farm. Ideally, the horse should be a gelding or a mare that has never been used for breeding and has never received blood or plasma transfusions.⁵ This will provide antibodies against locally important antigens.³ Plasma donors should have tested negative for equine infectious anemia and be blood type negative for Aa and Qa antigens and alloantibodies, since these are associated with neonatal isoerythrolysis. The plasma can be evaluated for IgG content before administration to calculate the required dose. Preferably, serum IgG should be >12 g/L. One liter of average quality plasma should raise the foal's IgG concentration by about 2 g/L.¹ The foal's serum IgG concentration should be measured repeatedly after administration because >1 transfusion may be necessary during the first 3 weeks to provide complete protection.

Up to 10 L of blood can be safely drawn from a donor horse of 450 kg body weight.⁵ Blood can be collected into plasma collection bags, (Baxter, Ontario, Canada: www.baxter.ca) containing citrate anticoagulant. Plasma is separated by sedimentation or centrifugation and, subsequently, transferred into plasma storage bags. Blood should be used within 2 hours or stored at 4° for up to 14 days; plasma can be stored frozen at -30°C for 12 to 24 months.⁵

Prevention

An important aspect of prevention of FPT is client education. Clients can help ensure that a mare has adequate colostrum quality by employing vaccination programs specific for their particular region. Mares should be housed in the area where they will foal for at least 4 weeks before the foal is born, in order that their immune system is able to produce environment-specific antibodies and concentrate these in the colostrum. This provides optimal protection for the newborn.

The environment, the pre-parturient mare, and particularly, her udder and perineal region, should be kept clean at all times. Supervised foaling programs for mares are a good way to detect and correct problems. They help ensure that the foal is healthy and able to stand and suck. Some systems rely on camping in front of the stall or camera supervision. Less labour intensive systems react when the mare lies down for a certain time. These are available as devices connected to a halter (Equi Fone[®] and Equi Page[®] www.foalingalarm.com) or a girth around the chest of the mare (birth alarm[®] www.birthalarm.com). More invasive methods include a vulva transmitter with a magnet (Foal alert[®] <http://www.foalalert.com/>) sutured into both lips of the vulva, the alarm is activated when the magnet separates.

Some veterinarians suggest that all foals should be routinely supplemented with colostrum;¹ however, there is no published evidence that this is beneficial. Nevertheless, it is important to have a supply of

Table 4: Jaundiced foal agglutination test⁵

1. Collect serum and red cells from foal and mare (in lithium heparin/citrated tubes); test works with colostrum (filtered through a gauze), but can give false-positive results
2. Set up seven tubes each with 1 ml saline
3. Make serial dilutions with mare's serum or colostrum: add 1 ml to tube #1 (1:2), mix and remove 1 ml from this tube into tube #2 (1:4), mix and repeat until tube #6 (1:64); discard 1 ml from the last tube
4. Add one drop of the foal's whole blood to each of the tubes and mix by agitation or whirly mixer
5. Centrifuge tubes for 2-3 minutes at 200-300g
6. Pour off supernatant

Results:

- Complete agglutination causes cells to remain firmly packed at the bottom of the tube = positive reaction
- Negative samples show free movement of cells
- Positive reactions are to be taken in a 1:16 or higher dilution

colostrum for those mares with poor quality or inadequate amounts of colostrum. Colostrum can be milked and stored frozen for 18 months without significant loss of IgG. Colostrum “banks” can be established with colostrum milked from mares after their own foal has suckled adequate amounts or from mares that have lost a foal.¹ One to two hours after birth, 200 to 250 ml can be safely milked from a mare without impairing her own foal's colostrum intake.¹⁶ The quality of stored colostrum should be evaluated before administration. In most cases, colostrum is thick, sticky, and yellow. Colour and consistency, however, are not reliable indicators for colostrum quality and specific methods to evaluate the Ig content should be used (eg, colostrometer or radial immunodiffusion). Colostrum should be free of anti-red cell antibodies to prevent neonatal isoerythrolysis (“jaundiced” foal agglutination test; Table 4).⁵ Ideally, stored colostrum should be obtained from a mare housed at the same farm as the recipient foal to provide optimal coverage with specific antibodies.

Summary

FPT is a major predisposing factor to many serious foal diseases, including sepsis, the leading cause of morbidity and mortality in foals. Many tests are available to detect low serum Ig concentrations in foals. Those tests based on quantitative or semiquantitative immunoassay are most accurate. When low serum Ig concentrations are detected before 12 hours of age, the foal can be treated by assisted nursing or oral colostrum

supplementation. When low serum immunoglobulin concentrations are detected at 24 hours of age, intravenous plasma can be used to increase the foal's humoral immunity.

These websites appeared within this article

- Prairie Diagnostic Services: www.usask.ca/pds (price list available on webpage)
 - SNAP[®] foal IgG: <http://www.idexx.com/equine/index.jsp>
 - Polymune[™]: www.veterinarydynamics.com
 - HiGAMM EQUI[®], Lake Immunogenics: www.lakeimmunogenics.com
 - Seramune[®] Equine IgG, Sera Inc: www.seramune.com
 - Baxter, Ontario, Canada: www.baxter.ca
 - Equi Fone[®] and Equi Page[®]: www.foalingalarm.com
 - Birth Alarm[®]: www.birthalarm.com
 - Foal alert[®]: <http://www.foalert.com/>
- (All websites accessed December 8, 2005)

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Dr. Katharina Lohmann is a faculty member in Large Animal Medicine at the Western College of Veterinary Medicine. Her special clinical interests are diseases of foals, gastrointestinal diseases, and sepsis in neonates and adults. Her research focuses on endotoxemia in horses.

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Dear Readers:

I regretfully announce that this is my last issue as Editor of *Large Animal Veterinary Rounds*. Since the inception of this series 5 years ago, I have greatly enjoyed guiding each issue to completion. Providing monthly clinical review articles that are written by Canadian veterinarians for Canadian veterinarians has been an enjoyable and fulfilling role for me. One of the great satisfactions of being part of *Large Animal Veterinary Rounds* has been our ability to deliver topical articles on current events in the veterinary world. One example that comes to mind is our article on anthrax in 2002, at a time when "bioterrorism" was becoming a new topic of conversation in North America. Other examples include the article about influenza, two issues on West Nile virus and, back in 2001, our inaugural issue on John's disease in beef cows.

Another source of satisfaction over the past 5 years has been the ability of the series to relay the wealth of review material generated by my colleagues at the Western College of Veterinary Medicine and other Canadian veterinary colleges. *Large Animal Veterinary Rounds* has also provided an opportunity to describe disease syndromes that are well recognized elsewhere, but which receive little attention in North America; for example, ruminal drinking in calves.

It has been gratifying to see the speed with which information has been disseminated via the Rounds series. Electronic communication, editing, and rapid translation has made it possible for material to appear in print in English and French within months of it first becoming public knowledge. I owe a great debt to our readers, the many authors who contributed to the series, and the support of Schering-Plough Animal Health for allowing me this opportunity.

Every dark cloud has a silver lining. I have recently changed jobs and taken a teaching position at Ross University in St. Kitts, West Indies. Education is the primary mandate of this teaching university and I am enjoying the new opportunities to learn about, and improve, educational methodology. As I look out of my window, I see ranks of white cotton wool clouds forming over the blue Caribbean Sea (as opposed to blue skies over a white landscape!) Hopefully, some of you will be able to take a break from your busy practices in Canada and come by for a visit. Thank you again for your interest and support of *Large Animal Veterinary Rounds*.



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