

EQUINE LAMINITIS

Nathaniel A. White II DVM MS, DACVS
Marion duPont Scott Equine Medical Center
VA-MD Regional College of Veterinary Medicine
Virginia Tech
Leesburg, Virginia 22075

Imagine your best mare has just been observed to have colic. Your veterinarian diagnoses a large colon volvulus, a fatal twist of the large intestine if surgery is not completed immediately. After being encouraged by a successful abdominal surgery correcting the problem, four days later the surgeon calls with new problem, laminitis. Your mare is lame in all four feet, but particularly in the front feet. There is a bounding pulse in the arteries coursing to the feet and the feet are hot. The mare treads as if walking on eggs and postures with her front limbs stretched out in front of her. Radiographs of the front feet reveal a change in the coffin bone position within the hoof. The bone is separating from the hoof wall with the tip of the coffin bone angling down toward the ground.

The pain is not relieved with pain relievers, special shoes or even surgery to relieve pull of the deep flexor tendon. The pain is constant and excruciating. Even with the best of treatments the disease progresses with penetration of the bone through the bottom of the foot. Euthanasia is your only real choice. How did it start; how did it progress so quickly? Why can't laminitis be prevented? Too often this scenario is experienced by owners and veterinarians.

Laminitis or inflammation and degeneration of the lamina in the horse's foot is unique to the horse. The problem is both a physical problem due to the way the hoof lamina support the horses weight and the vascular system in the foot, which is particularly sensitive to systemic inflammation originating in the intestine or uterus.

Research on equine laminitis has unraveled many of the physiologic responses that occur within the horse's foot. However, the exact cascade of events, which lead to damaged lamina with eventual separation of the coffin bone from the cornified hoof is not completely understood.

Risk Factors

The disease is most often associated with diet, diet changes, toxins or gastrointestinal disease. One constant with intestinal diseases is disruption of the intestinal mucosa by such diseases as Salmonellosis, Potomac Horse Fever, carbohydrate overload, or bowel infarction.¹ As the mucosa is damaged, endotoxemia commonly occurs prior to the onset of laminitis² and specific amines are released into the circulation.³ Other diseases including retained placenta also have endotoxemia as a common mediator of systemic shock and carry an increased risk for laminitis. Horses eating excessive amounts of grain, particularly a different feed than normally ingested are more likely to have laminitis. In cases of anterior enteritis horses with weights of >550 kg and those with bloody gastric reflux were more likely to have laminitis.⁴ Horses with pituitary adenoma are at higher risk of laminitis as are ponies which have a tendency toward insulin resistance.⁵

Horses with have excessive weight bearing on one limb compared to the contralateral limb are at risk for unilateral laminitis on the overloaded limb. This is most frequent after limb fractures, infectious arthritis or tenosynovitis. This form of laminitis appears to be a mechanical cause of laminitis.

Pathogenesis

No doubt there are multiple mechanisms that can lead to laminitis which eventually leads to failure of the foot support system or chronic foot deformity. There are several hypotheses regarding the events which lead to laminitis. Changes in the cecal mucosal barrier have been documented after carbohydrate overload.¹ Acidosis in the cecal lumen with death of gram negative bacteria occurs during the first few hours after carbohydrate overload.² A systemic inflammatory response to this intestinal insult causes a response of the vasculature with activation of platelets and white blood cells. The laminar disease originates in the vasculature and the acute lesion is indicative of ischemia with vascular damage and laminar edema. Some of the early work eliminated some systemic factors or mediators as cause of the disease. Inhibitors of histamine, prostaglandin, and coagulation have changed or modulated the clinical signs, but did not alter the course of the disease.^{6 7} Increased upregulation of the genes for IL-1beta and IL-6 in affected lamina suggest a primary inflammation originating in the foot but the “trigger factor” initiating this response has not been identified.⁸

Based on the response to treatment, the pathogenesis of laminitis was thought to be related to endotoxic shock and vascular coagulopathy. In some early work, administration of heparin at a low dose (40 units/kg subcutaneously) prevented laminitis in approximately 80% of horses with induced experimental carbohydrate overload. Horses treated with heparin during anterior enteritis had a lower incidence of laminitis supporting heparin as an effective preventative.⁴ Administration of anti-endotoxin antiserum has also been successful in preventing the majority of cases of laminitis when it was experimentally administered at the same time as a starch overload. However, neither antiserum nor heparin has prevented all cases of laminitis. Unlike experimental treatments, the administration of endotoxin antiserum and heparin in natural cases frequently starts after clinical signs are evident and laminar damage has already occurred. Recent work has shown that compounds which inhibition of platelet activation also prevent laminitis if administered at the same time as the carbohydrate overload used to create the disease.⁹

There is debate over the alterations of blood flow during the onset of laminitis. Early in the process there is an alteration of blood flow in the foot. Thermography suggests increased flow during the developmental phase of laminitis based on increased heat in the foot.¹⁰ Work using radioactive albumin and microspheres reported decreased flow in the dorsal hoof lamina.¹¹ However, alterations of the blood flow are different at different times during the onset of the disease. Trout et al. suggested that capillary flow is increased in the prodromal stage of laminitis.¹² The existence of arteriovenous anastomoses (AVA) within the foot apparently allows bypass of the capillaries during the acute stage of the disease.¹³ Though one report relates ischemia due to the dilatation of the AVA, this work does not take into account the early capillary lesions and capillary filtration changes prior to recorded changes in blood flow.¹⁴ Though hypothetical, it appears that AVA dilatation allows increased blood flow to the lamina

and results in an increased digital pulse pressure and heat without perfusion in the capillary tuft in the dorsal lamina.

The site or mechanism of altered capillary flow has been investigated by pressure and flow measurements including systemic pressure, arterial pressure, digit weight, venous outflow and occlusion pressure, capillary filtration coefficients, plasma and lymph oncotic pressure, and osmotic reflection coefficient.¹⁴ In horses that developed laminitis (10-16 hours after carbohydrate overload before clinical signs are seen) there was an increase in both the precapillary and postcapillary resistance. The postcapillary resistance was much higher and appeared to be the predominate reason for the reduced capillary flow.⁶ At the same time an increase in the laminar interstitial fluid pressure exceeds the capillary closing pressure. This pressure increase compresses the capillaries subsequently reducing blood flow. This chain of events is comparable to a compartment syndrome in muscle-fascial compartments except that the cornified hoof and the distal phalanx, both of which have minimal compliance, make up the compartment in the foot. Fluid trapped within the laminar compartment cannot escape, and normal weight bearing exerts additional tissue pressure. As of yet, the cause of the postcapillary hypertension or change in the capillary hemodynamics is not known. Though vasoactive mediators such as endothelin or 5-hydroxytryptamine are suspected, the specific initiator of these events has not been identified.

Vascular damage with alterations in laminar capillary permeability still appears to be part of the pathogenesis. After the onset of laminitis, microthrombi are present in the capillaries of the affected lamina, but there is no information that shows whether the coagulopathy is the primary cause or secondary to an ischemic insult.^{15 16 17} Histologic examination of the lamina during the early stages of laminitis 12-18 hours provided evidence of endothelial swelling within capillaries and small arterioles. Edema in the extravascular space constricts the capillaries decreasing blood flow and increasing the diffusion distance for oxygen and nutrients. The inflammatory response in the lamina or a direct action of specific compound activates metalloprotenase with enzymatic degeneration of the basement membrane with eventual separation of the cornified hoof from the capillary tuft.^{18 19 20 21} The role of neutrophils and platelets in this inflammatory response is now the focus of research.

Several vasoactive mediators have been suggested as the trigger substances in reducing capillary flow. Though histamine has not been totally ruled out, its ability to increase permeability does not appear to be a significant factor as the foot already has very permeable vasculature. Endotoxin when administered in low doses during a prolonged infusion causes precapillary constriction rather than a predominate postcapillary constriction seen in the experimental laminitis model. Its role in initiating a systemic inflammatory response syndrome maybe be related to the vascular reaction and it has been shown to increase the arterial constriction response, stimulate increases in 5-HT and tumor necrosis factor, and decrease the endothelial response to acetylcholine.²²²³ Serotonin, known to be released during carbohydrate overload, causes postcapillary constriction, but this has not as yet been identified as a causative factor.²⁴ Recently endothelin has been shown to be increased in the lamina of horses with chronic laminitis with higher concentrations than found in the acute cases. Its role as the initiating vasoconstrictor during acute laminitis is not confirmed.

Another form of laminitis occurs in horses with Cushing disease (hyperadrenocorticism) caused by a pituitary adenoma with subsequent insulin resistance. Though the mechanism is unknown, excess glucocorticoid likely causes vascular changes and potentially affects the hoof growth.^{25 26 5} Unlike the acute onset of laminitis following a gastrointestinal disturbance, hyperadrenocorticism or insulin resistance frequency causes a slower onset of laminitis, which is recurrent and often difficult to treat.

Excessive weight bearing on one limb does not appear to cause a systemic response and the resulting laminitis is restricted to the overloaded foot. Though no one has investigated the mechanism, it appears the excessive weight causes a compression of the vasculature in the lamina and eventually leads to ischemia and degeneration of the lamina. Lameness is not seen due the lameness which is usually present in the opposite leg due to infection or a fracture, so that heat and digital pulse increases are the first signs. The horses weight in relation to foot size may be a risk factor for this type of laminitis.

Clinical Signs

Clinical signs of acute laminitis include increased digital pulse, heat in the feet, and lameness. An increase in the digital pulse and increased heat in the feet often precede lameness.²⁷ On average lameness often starts at 36 hours after acute carbohydrate overload, but may start as early as 24 hours and as late as 48 hours. After ingestion of supernatant from black walnut hard wood or shavings, signs of laminitis can occur within 6 to 8 hours.^{28 29}

The lameness starts as discomfort with treading from one foot to the other. Obel originally described the lameness and applied the following grading system.

Obel grades of lameness:

Grade 1= Alternately lifting feet; not lame at the walk.

Grade 2= Stiff and resists turning at the walk and lame at the trot.

Grade 3= Lame at the walk; stilted gait; resists lifting feet.

Grade 4= Will not move unless forced.

The signs of laminitis are variable, from mild to very severe. If the reaction and laminar change in the foot is very rapid, the pain is frequently severe. In some cases rotation or total separation can be seen in 48-72 hours after the onset of pain. The variability is probably due to factors such as weight, the severity of systemic reaction or intestinal damage.

There are several characteristic stances, which horses assume when they have laminitis (Figure 1). The hind legs, which are usually less severely affected, are move forward underneath the body to support more weight.

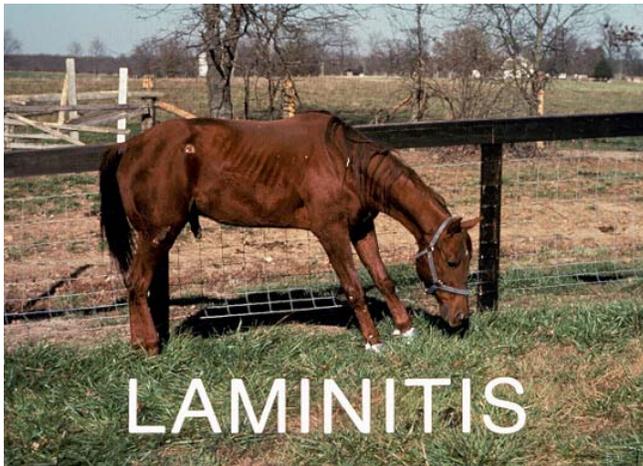


Figure 1: The classic stance of a horse with acute or chronic laminitis. The front feet are extended out in front of the body in an attempt to ease the pain created when bearing weight.

The front limbs can either be placed out in front of the body in an effort to decrease weight bearing or moved back underneath the body (standing on a dime) with flexed limbs to reduce tension on the deep flexor tendons (Figure 2). The back and gluteal muscles are tense and the horse never looks comfortable. While walking horses land on



Figure 2: A horse with acute laminitis standing with the rear limbs under the body and the front limbs back underneath the body.

their heels with the toe elevated. The toe is then eased to the ground. If laminitis affects the rear feet more than the front feet, the gait may include exaggerated hiking of the feet similar to stringhalt. This appears to come from pain as each foot bears weight and causes a withdrawal reflex.

The hoof is painful to palpation with hoof testers specifically over the toe. The horse actively resists hammering or other foot manipulations. Horses are reluctant to stand on just one front foot for any length of time. When the distal phalanx sinks there is a depression around the coronary band most prominent at the toe.

Lateral radiographs are helpful to detect changes in the position of the coffin bone (Figure 3). The bone can either rotate or sink. When the bone sinks due to severe



Figure 3: Radiograph of the hoof showing the front of the coffin bone (distal phalanx) no longer in parallel alignment with the front of the hoof wall. The new hoof growth is abnormal.

degeneration of the lamina at both the toe and heel, the coronary band recedes below the level of the hoof wall.³⁰ In the case of sinking of the distal phalanx, since there is no rotation, the coffin bone often appears in normal position on radiographs. Measurement from the outer hoof wall to the dorsal border of the distal phalanx should be from 1.5 -1.7 cm both at the proximal edge and the tip of the bone (for the average sized thoroughbred). Measurement greater than this indicates ventral displacement (sinking) of the distal phalanx.

As the disease progresses and hoof growth is altered the hoof shape changes. As the laminar degeneration occurs the coffin bone rotates away from the hoof wall. The pressure on the sole from the distal edge of P3 causes the concave sole to become flat. In extreme cases the distal phalanx penetrates the sole with necrosis of the solar lamina and eventually damage to the coffin bone (Figure 4). As the hoof attempts to heal and grow, the new hoof wall continues to grow separate from the bone. There is decreased hoof growth at the toe causing a dishing of the hoof wall (Figure 5). In these cases the horse continues to have pain and lameness and the foot grows abnormally until corrective measures are taken.



Figure 4: A severe cases of laminitis with distal phalanx rotation and subsequent penetration of the sole.



Figure 5: Chronic laminitis with increased hoof growth at the heels and dishing of the front of the hoof wall due to the separation of the lamina from the distal phalanx.

Treatment

Understanding the inflammatory and vascular responses helps to formulate a rational approach to treatment. The stages of the disease have been labeled; 1) **Prodromal Stage**, the disease process prior to the onset of lameness; 2) **Acute Stage**, the time of initial pain and systemic response; and 3) **Chronic Stage**, the period of separation of the distal phalanx and the hoof with failure of appropriate hoof growth and chronic lameness.

Ideally treatment would begin prior to when endothelial damage and platelet/WBC aggregates occur.⁹ However, there are no signs during the prodromal stage, unless endotoxin causes colic, ileus or signs of shock. Once these signs are observed one can assume that changes in the feet are already present. During the prodromal stage the use of low dose heparin, endotoxin antiserum, drugs, which inhibit platelets and cryotherapy of all the feet are indicated when endotoxemia is present or predicted. Heparin used in experimental carbohydrate overload prevented laminitis in a majority of horses. Clinically this has had marginal results likely determined by when treatment was initiated.^{31 32 4} Nitroglycerin ointment applied over the digital arteries (approximately 10-15 mg) per foot has also been recommended both at this early stage and during the acute stage of the disease when a digital pulse is felt.³³ Unfortunately this has been met with clinical success due to lack of cutaneous absorption.

Maintaining the feet at 4 degrees centigrade after carbohydrate overload has prevented experimentally induced laminitis. This apparently decreases the inflammatory response and prevents initiation of enzymatic degradation of the basement membrane.³⁴³⁵ Currently this appears to be the most effective means of prevention if applied during the prodromal stage before the initial inflammatory reaction is initiated.

Initiation of treatment is particularly important during high risk diseases such as small intestinal enteritis, colitis, or retained placenta. The failure of these treatments to work in clinical cases is probably due to administration after the prodromal stage when laminar vascular damage has already occurred. Since there are no signs of the lameness until later in the disease when the lamina fail to support the hoof, the disease process has already advanced by the time the clinician initiates therapy.

Once the acute stage of the disease is first recognized treatment should be directed toward preventing further vascular alterations and further degeneration of the lamina. This is difficult because the primary treatment for compartment syndrome is decompression. Decompression has been attempted in the past by drilling of the hoof

wall until bleeding occurred or incising the coronary band to reduce vascular pressure at the coronary band. Unfortunately the laminae are made up of many microscopic compartments and are not decompressed with a few drill holes in the dorsal hoof wall. Thinning the dorsal hoof wall has been used and is felt to be valuable in the acute cases. The hoof wall is rasped until it is soft and flexible to touch. Often several hours after this is completed, serum will be seen oozing out of the softened area. Dorsal hoof wall resection is not indicated at any time as it weakens the hoof structure even though pressure may be relieved. The damage to lamina and the shear stresses applied along the border of the resection can often cause severe pain. Ideally horses should be lifted off their feet to help reduce the pressure of weight bearing. Horses that stay recumbent for longer periods seem to benefit but the disease can still progress despite slinging or frequent recumbency.

Systemic therapy in the acute phase is directed toward reducing compartment pressure, increasing flow in capillaries, and preventing untoward effects of tissue degeneration. DMSO, administered intravenously (20-100 mg/kg diluted in 1 liter of saline), may reduce edema in the foot compartment similar to its affect on CNS edema. However, its greatest effect may be to reduce damage from reperfusion injury during the prodromal stage of the disease. It may also be helpful in reducing inflammation created by generation of oxygen or hydroxyl radicals during ischemia and reperfusion after low flow through the lamina. Though reperfusion injury has not been proven to occur in the hoof during laminitis, sequence of events likely occur in the foot similar to that seen in the serosa of the small intestine.

Alpha blockade is used in hopes that it helps to reduce the vasoconstriction within the laminar vasculature. There is no proof that the postcapillary constriction is reversed by alpha blockade or that the reduction of systemic blood pressure is beneficial, but there is often reduction of the bounding pulse and easing of the pain in some cases. Several drugs have been used, but acepromazine is the most readily available and appears to be effective at 0.01 mg/kg intravenously every 4 hours.

Flunixin meglumine or phenylbutazone are also indicated to reduce pain and inflammation. The effect on the digital vasculature is unknown, though it probably has some effect due to inhibition of prostaglandins. The use of heparin in the acute phase is controversial. If it is used after the onset of lameness, an anti-coagulating dose (100 units/kg, IV, QID) is recommended compared to the low doses (40 units/kg, SQ, TID) used as a preventative.

To prevent bacterial growth in the compromised tissue, antibiotic therapy is considered important during the period of laminar injury. A broad-spectrum combination such as penicillin and gentamicin is best. Bacterial invasion during chronic laminitis should be considered a different problem that requires drainage and possible treatment for anaerobic bacteria using antimicrobials such as metronidazole (7.5 mg/kg per os TID). Once the acute stage of laminitis has ended, the infection found in the lamina is often due to contaminants being trapped in unhealthy tissue. The bone is rarely infected, but once infected it is rarely resolved sufficiently to allow the horse to return to normal.

Physical therapy is helpful during the acute phase of the disease. Ideally, the affected horse should not be allowed to bear weight on its feet. Since this is not possible unless the horse will lie down, frog pads are used to relieve some of the pressure on the hoof wall by placing more pressure on the frog and heels. Styrofoam pads are used in a

similar fashion to cover the entire foot and allow the horse to crush this material into a form fitted pad. The resulting pad with its impression of the foot is attached to the feet to provide support over the entire foot thereby relieving pressure on the hoof wall. This helps relieve pain and hypothetically helps to decrease compartment pressure and improve circulation if only slightly. In some cases the most effective therapy appears to be the use of moistened sand 3-4 inches deep in a stall or pen which gives even support across the entire foot. The horse can adjust the hoof angle in the stand to provide the position with the most comfort. Thick stall mats made of polyurethane are also effective in relieving lameness with horses willing to stand for longer periods.

Some horses have relief by elevating the heels 15-20 degrees with plastic pads (Figure 6). The horse's feet are left at this increased angle if there is relief of pain.



Figure 6: Elevation of the hoof angle with a soft pad helps relieve tension on the deep digital flexor tendon and reduces concussion.

The hoof angle is decreased slowly by sequential removing some of the pads after about three weeks. The heel elevation should not be removed too rapidly as the lamina take weeks to heal. Removal is completed in stages over 3-6 weeks. If pain is increased when the hoof angle is increased the pads should be immediately removed. Horses should not be urged to walk during the acute phase of laminitis to prevent excessive wall pressure and pull of the deep flexor tendon.

There are many reports of corrective trimming and shoeing for laminitis and distal phalanx rotation. Shoeing in the acute phase (24-48 hours) should be avoided so there is no further trauma to the lamina and excess pressure is not placed on the hoof wall. Once the coffin bone appears stable the goal is to trim the foot so that the distal phalanx is realigned to its proper position in relation to new hoof growth and the ground. This may have to be completed in stages so as not to disrupt healing of the lamina with excess tension from the deep digital flexor tendon. The primary purpose of applying shoes is to protect the foot, relieve dorsal hoof wall pressure, prevent uneven sole pressure, provide support by prominent support of the frog and heels and minimize the break over leverage by not allowing the shoe to extend past the tip of the distal phalanx. If this cannot be accomplished, shoes should not be applied. Applications of egg bar shoes resulted in increase blood flow to the feet.³⁶ This supports the use of shoes which increase the support to the foot.

Often a reverse shoe with pad or reverse heart bar shoe provides the best relief of pain for horses with severe laminitis (Figure 7). The shoe is designed so that it 1) provides support to the frog and heels, 2) has short branches which do not extend beyond the tip of the distal phalanx and 3) has an open toe to reduce wall pressure at the toe of the foot. No type of shoe can be predicted to be a perfect resolution for a particular case of laminitis. Therefore, no matter what type of shoe is used, if it does not provide some relief, it is best discarded for another shoeing formula.



Figure 7a



Figure 7b

Figure 7: A reverse heart bar shoe (a) or reverse plastic glue on shoe with soft acrylic sole support, can be help relieve lameness and support the foot during the period of hoof growth and realignment.

In severe cases release of the tension on the deep flexor tendon is helpful to relieve pain and allow more normal hoof growth. The check ligament desmotomy is recommended for chronic cases where foot deformity cannot be corrected with trimming and shoeing.³⁷ There should be adequate hoof growth, even if the foot is misshaped, prior to completing this technique. The release of the check ligament is often enough to allow normal hoof growth and to correct lameness due to the chronic hoof deformity.

The deep digital flexor tenotomy is performed as last resort or salvage technique. The procedure is considered when there is continued coffin bone rotation despite treatment or if the pain cannot be controlled. Deep flexor tenotomy can be done just caudal to the pastern within the tendon sheath. It is also completed in the metacarpal region proximal to the tendon sheath and distal to its union with the distal check ligament.³⁸ Cutting the deep flexor within the distal sheath appears to allow more complete release with subsequent return of a more normal hoof conformation. The technique can be completed with the horse standing by palpation or using an ultrasound guided dissection.

Alternative therapies have not been successful in curing laminitis. Acupuncture has not been shown to help reduce chronic lameness due to laminitis.³⁹ Though some

pain relief may be possible, acupuncture should not be used with other medication or hoof support know to help treat the laminar disease. The claims for use of massage, lasers, magnets or other types of therapy have not been substantiated

Prognosis

The severity of the laminar damage created by laminitis cannot be predicted in the initial phases of the disease. If the inflammatory insult is severe enough, no systemic therapy or physical support will be able to prevent distal phalanx rotation or sinking. Early systemic treatment prior to signs of laminitis appears to be the best hope for preventing a severe lesion.

Pain and the distal phalanx angle in relation to the hoof have been related to the prognosis. If the pain is severe and is not readily controlled by analgesics, shoeing or foot support, the prognosis is poor. A rapid response to therapy on the other hand is an indicator of a good prognosis. Similarly, rotation of the coffin bone of 15 degrees or more is related to a poor prognosis. Horses with 5 degrees or less distal phalanx rotation generally have a good prognosis as long as appropriate treatment is provided.⁴⁰ Even with severe rotation, evidence of regeneration of the hoof indicates the potential to reposition the coffin bone within the hoof although this can take months of appropriate trimming.

Horses with sinking or distal displacement of the coffin bone have a poor prognosis.³⁰ Medical treatment, corrective shoeing, or time to allow new hoof growth does not readily repair the lack of support that develops during this type of severe separation of the hoof and coffin bone.

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