Preventing Laminitis in the Contralateral Limb of Horses with Non-Weight-Bearing Lameness  (21-Nov-2003)

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Abstract
The weight-bearing foot should be mechanically supported in a way that preserves laminar perfusion during full loading. This goal is achieved by (1) raising the heels and moving the functional break over point back so that the horse preferentially stands with a third phalanx (P3) palmar angle of 20º, and (2) providing arch support. The support device should be applied as soon as possible after injury.

1. Introduction
Laminitis in the contralateral limb is a well-recognized and potentially devastating sequela in horses with complete fractures, sepsis involving a synovial structure, catastrophic "breakdown" injuries, and other conditions that cause unilateral non-weight-bearing lameness [1-3]. Tremendous progress has been made in the field of equine orthopedic surgery, yet laminitis in the contralateral limb remains an all too common complication [3]. Despite successful surgical repair, laminitis may develop in the opposite limb, and ultimately, necessitate euthanasia truly a case of "the surgery was a success, but the patient died".

The mechanism of contralateral limb laminitis has not been well studied. Based on extensive clinical observation, it is my opinion that laminitis in these cases is load-induced and is related to two key factors: (1) the length of time that the weight-bearing foot remains fully loaded and (2) the structural integrity of that foot. The longer the horse continues to overload the supporting foot, the greater the risk for laminitis in that foot [2]. In my experience, horses that are unable or unwilling to bear any weight on the diseased limb, even for a few seconds at a time, are more prone to developing laminitis in the contralateral limb than are horses that hobble or shuffle around a little, periodically relieving the weight-bearing foot by briefly or partially loading the diseased limb.

Structural integrity of the supporting foot may be as important as the duration of overload. I have observed that contralateral limb laminitis is more likely to develop in a foot with a thin sole, low heel, negative palmar angle, hoof wall defects, or other structural abnormalities than in a healthy, more robust foot. Also, in these weak feet, contralateral limb laminitis often manifests earlier than in a stronger foot and is more difficult to manage successfully.

Venographic studies provide an important clue to the likely mechanism of contralateral limb laminitis, and thus, to its prevention. When performing venography, the foot must be slightly unloaded i.e., tension in the deep digital flexor tendon (DDFT) must be partially relieved for the laminae of the dorsal hoof wall to fill with the contrast agent [4] (simply "unlocking" the carpus by applying a little pressure to its palmar aspect sufficiently relieves tension in the DDFT to allow vascular filling in the dorsal laminae). Even in a normal foot, the dorsal laminar vessels do not fill when the limb is fully loaded (carpus locked in extension, opposite limb held up) during injection of the contrast agent (Fig. 1). It could, therefore, be inferred that in a foot under constant load, the unrelenting pull of the DDFT on the coffin bone, and thus, on the dorsal laminar attachment, compromises blood flow through the dorsal laminae, jeopardizing the health and integrity of the laminar attachment.
In vitro studies have shown that raising the hoof angle by 23º using heel wedges decreases DDFT tension by at least 60% [5]. Use of mechanical support to substantially decrease tension in the DDFT of the weight-bearing limb is the basis of the method I use to minimize the risk for contralateral limb laminitis in horses with severe, unilateral limb lameness. This paper describes the principles and application of this technique.

2. Materials and Methods

Principles - The two essential goals for mechanical support of the weight-bearing foot are these:

1. substantially decrease tension in the DDFT
2. support the cup of the foot (i.e., provide arch support)

These goals must be implemented as soon as possible after severe lameness develops. Time is of the essence in preventing contralateral limb laminitis. Blood flow to the laminar corium of the supporting foot is compromised as soon as unrelenting load begins (i.e., at the onset of severe lameness in the primary limb). Waiting for a problem to occur i.e., waiting until the horse is showing signs of discomfort in the supporting limb before doing anything about it can be a fatal error. This syndrome is well underway by the time the horse shows the first signs of discomfort.

The means I use to achieve these goals consist of an adjustable wedged slipper-type shoe and elastic polymer sole packing material. Other means may be effective, provided that these goals are met. In applying these basic principles, it is also important to tailor the support system to the unique characteristics and requirements of the foot. Before applying any mechanical device, it is essential that the horse's foot conformation be evaluated. The health and strength of the hoof capsule and the relationship between the third phalanx (P3) and the hoof capsule dictate the extent to which hoof angle and break over must be altered to achieve these goals. Thus, it is important to define the starting point: The quality and shape of the supporting foot.

In addition to visual inspection, a lateral radiograph should be taken of the foot. For this purpose, the X-ray beam should be centered at the palmar margin of P3 (0.50 - 0.75 in above the bearing surface of the hoof wall in most horses), and radiopaque markers should be used to delineate the dorsal hoof wall and the ground surface [6]. Pertinent radiographic assessments include the angle of the palmar, the depth of the sole, the width of the dorsal horn-lamellar zone, and the distance between the coronary band and the extensor process of P3 [7]. Palmar angle is the angle of the palmar (or plantar) margin of P3 relative to the ground surface. In most horses with healthy feet and strong heels, it is in the range of 3° - 5°.

Application Decreasing DDFT Tension - The strategy I use to achieve this goal involves raising the heels 10° (using two 5° wedges) and setting the functional break over point back far enough that the horse preferentially stands with a palmar angle of at least 20°. While various mechanical support devices may be suitable, I have had greatest success with the Modified Ultimate [a]. This device consists of a heavy-duty plastic cuff to which two 5° heel wedges are screwed (Fig. 2).

It is important to note that raising the heels is not sufficient on its own. Functional break over must be moved back far enough that the horse can easily pivot at the coffin joint, self-adjusting its palmar angle to find the most comfortable position; this more comfortable position maximally reduces DDFT tension and minimizes the "cookie cutter" effect of the thin palmar margin of P3 on the solar corium.

In addition, crushing of the heels can be expected when the heels are raised to this extent without moving break over back. This situation can be disastrous if the supporting foot already has compromised heels. By moving the pivot or break over point back well under the foot, excessive load on the heels can be relieved simply by rolling forward onto the toe. The ability to self-adjust the hoof angle and heel load seems to offer tremendous mechanical advantage and is an important
component of this technique.

For horses with a positive palmar angle (i.e., wings of P3 higher than the apex), the functional break over point should be under or just behind the apex of P3 to achieve the desired effect. For horses with a zero palmar angle (wings of P3 level with the apex) and those with a negative palmar angle (wings of P3 lower than the apex), the functional break over point must be under the center of the coffin joint (Fig. 3). The lower the initial palmar angle is, the further back break over must be moved for the horse to achieve and maintain a palmar angle of approximately 20º.

It is worth reiterating that the objective of this procedure is to create a dynamic situation in which the horse can easily self-adjust its coffin joint angle to minimize DDFT tension and sole pressure and thus, maximize laminar and solar perfusion. As the starting point is different for each foot, each case must be approached with an eye to the structural characteristics of that particular foot.

For example, in a horse with a broken back hoof-pastern axis, low heels, and a palmar angle of -5º, raising the heels 10º has less of a beneficial effect than it would in a horse with strong heels and a palmar angle of +5º. In fact, changing the palmar angle from -5º to +5º (i.e., raising the heels 10º) can actually increase tension in the DDFT by altering the pastern and fetlock angles. (In a horse with a palmar angle of -5º, the pastern is more vertical, and the fetlock is straighter than normal. This configuration results in less tension than normal in the DDFT by shortening the distance over which the tendon must travel to its insertion. When the heels of this foot are raised 10º, the fetlock drops slightly, which increases the distance over which the tendon must extend, and thus, increases tension in the DDFT).

In the horse with a negative palmar angle, break over will need to be moved further back than for the horse with a positive palmar angle to achieve the desired 20º palmar angle of P3 relative to the ground. The mechanical goals of this procedure are most difficult to achieve in horses with a negative palmar angle, yet these are the patients who most require this type of support.

The functional break over point on the support device I use is set far enough back that it does not need to be altered for most horses with a zero or positive palmar angle. In horses with a negative palmar angle, break over may need to be moved back slightly by shaving the underside of the device with a hoof rasp. This support device can be applied over a shoe, if necessary. However, leaving the shoe on limits the mechanical advantage of the device in that the functional break over point may be further forward than is desirable.

Arch Support - Arch support consists of filling the cup of the sole (the "arch" of the foot) with an elastic yet resilient polymer material. There are now several suitable products commercially available. Depending on time constraints, the polymer is either pressed into the solar surface of the foot before it sets up, or it is shaped into an approximately 0.50 in-thick pancake and placed inside the support device, like an insole in a shoe, before the device is applied to the foot (Fig. 2). Conformation of the sole dictates how effective the material will be in providing support. A sole with a deep cup is structurally stronger and has a greater inherent mechanical advantage than a flat or dropped sole (which, in addition to being structurally weaker, may be indicative of underlying pathology). The polymer support material will thus be most effective in horses with a deep cup, but it is perhaps most important in those with little or no cup.

Note: When applying the support device over a shoe rather than to a bare foot, more of the polymer is needed to fill the cup of the sole and the space created by the shoe.

Getting the Device onto the Foot - Application of mechanical support to the weight-bearing foot in a horse with a non-weight-bearing lameness can be a challenge. However, it is by no means impossible. There are several options for applying mechanical support in this situation:

1. Apply the device while the horse is under general anesthesia (e.g., after surgical treatment of the primary condition or during short IV anesthesia for horses with septic arthritis/synovitis).
2. Use a sling to support the conscious, sedated horse while the device is applied (Fig. 4).
3. For fractures or breakdown injuries, stabilize and support the lame limb using a cast or bandages and splints; then, quickly lift the weight-bearing foot onto the device (see below).
4. For conditions in which the limb is stable (e.g., septic arthritis/synovitis, unilateral laminitis), use regional anesthesia to desensitize the lame limb or use short IV anesthesia before applying the device.
5. When the horse is recumbent in its stall, a person can slip quietly into the stall, sedate the horse (e.g., detomidine [b] IV into the most accessible vein), and apply the device to the foot while the horse is lying down.
Each option has its advantages and drawbacks. If the horse is not going to surgery immediately or if no sling is available, one of the other options should be used. The key is to apply effective mechanical support to the weight-bearing foot \textit{as soon as possible after the initial injury or disease develops}, using whatever means are available. For example, a make-shift sling can be fashioned using an overhead beam and pulley, a mechanic's hoist, a back hoe, or hydraulic lifting equipment. Ingenuity can be life-saving in this situation.

**Securing the Device to the Foot** - I use a device that consists of a heavy-duty plastic cuff to which two 5° wedges are screwed. Once the wedges are secured to the cuff, the horse's foot is slipped into the device, and the cuff is secured to the hoof wall with a bonding material [c] or adhesive bandage [d], as shown in Figure 5. When using the adhesive bandage to secure the cuff to the hoof, it is important to first place a padded cotton wrap over the pastern and coronary band to minimize pressure on the coronary vessels.

The cuff on this device can be adjusted for a snug or loose fit. If the device is applied while the horse is recumbent or supported in a sling, there is time to fit the cuff to the wedges for a snug fit on the foot. If option 3 (above) must be used, a modification is needed, because the practitioner has only a couple of seconds and perhaps only one opportunity to fit the device to the foot. In this situation, I fit the wedges to the cuff for a loose fit and place a pancake of polymer support material inside the cuff as described earlier. Having first stabilized and supported the lame leg, the device is placed on the ground beside the weight-bearing foot, and the foot is lifted and quickly slipped into the support device. The cuff is then secured as described above.

Regardless of how mechanical support is provided, it is very important that the device is well secured to the foot. These horses \textit{cannot afford to lose their mechanical support} for even a few hours. A sudden increase in tension in the DDFT and thus, on the laminar corium, can be devastating. For this reason, subsequent radiographs of the foot should be taken with the device on until the foot no longer needs this mechanical support.

**Evaluating the Device** - Whenever possible, another lateral radiograph should be taken after the support device is applied. It is important to determine whether the device met the mechanical goal of enabling the horse to maintain a palmar angle of at least 20°. Failing to sufficiently relieve tension in the DDFT is the primary reason mechanical support fails to protect the weight-bearing foot.

This second radiograph is also important, because it establishes a new baseline for subsequent monitoring. When radiographing the foot with the support device on, the image will be magnified, because the device creates a gap of up to 1 inch between the foot and the cassette. This magnification will affect any measurements being made for the purposes of monitoring for soft tissue changes (e.g., dorsal horn-lamellar zone width) [7]. Thus, it is useful to establish a new (magnified) baseline for these indices as soon as possible after applying the support device.

To make radiographic monitoring easier, I tape a length of wire to the dorsal hoof wall as a radiopaque marker before bandaging the support device to the foot. This way, the bandage does not need to be removed when lateral radiographs are repeated for monitoring purposes.

If radiographs cannot be taken for whatever reason, a farrier who routinely uses radiographs as a tool for assessing and balancing feet can be a valuable asset. That farrier should be able to estimate the palmar angle simply by evaluating the hoof capsule.
**Maintenance** - The weight-bearing foot should be supported as described until the horse is able to bear full weight on the injured/diseased limb. Frequent reassessment during that time is important, however. Use of the support device for longer than 3 - 4 wk at a time typically results in accelerated toe and sole growth and decreased heel growth, especially in horses that started out with low heels. Thus, hoof conformation changes over time in a way that gradually decreases the palmar angle and lessens the mechanical advantage of the support device.

I reassess the weight-bearing foot frequently and, when necessary, remove the support device, trim the foot, and reapply the device to restore the desired mechanical effect. If possible, the foot should be trimmed and the support device reapplied without setting the foot down while unsupported. If the foot must be set down for a short time during the procedure, the device should be slipped back on, and if indicated, temporarily secured with an adhesive bandage.

Once the horse is bearing full weight on the injured/diseased limb, mechanical support can be discontinued. The foot is then trimmed using the fourpoint method (which maintains break over close to the apex of the frog).

**3. Results**

**General Observations** - Although tension in the DDFT after application of the support device has not been objectively evaluated, subjectively the tendon feels less taut once the foot is placed in the support device. Venographic evaluation confirms that setting up the foot so that the horse can maintain a palmar angle of approximately 20º preserves vascular perfusion of the dorsal laminae during full weight-bearing. Figure 6 shows a venogram of a foot wearing a support device that achieves a palmar angle of 20º. Even though the foot was fully loaded during injection of contrast material, the dorsal laminae are well perfused.

![Figure 6. Venogram of a normal foot wearing a support device that maintains a palmar angle of 20º. This foot was fully loaded during dye injection and radiography, yet the dorsal laminae (arrow) are well perfused (compare with Fig. 1B).](https://www.ivis.org)

Vascular perfusion in the heel area is decreased relative to the normal foot shown in Figure 1, which is to be expected with this degree of heel elevation. Provided that the horse is frequently reevaluated, the foot is trimmed, and the device is refitted as necessary, I have encountered few problems with the use of this support device for periods of 2 - 3 mo. In fact, in horses that start out with low heels and/or thin soles, the accelerated sole growth is a bonus of this procedure.

**Clinical Results** - This technique has been used in several hundred high-risk patients, including horses with complete fractures, infected puncture wounds, severe lacerations, catastrophic breakdown injuries, and severe unilateral laminitis. Table 1 summarizes the outcomes of 86 representative cases. The overall incidence of contralateral limb laminitis in these high-risk horses was only 2.3%.

<table>
<thead>
<tr>
<th>Clinical Condition</th>
<th>Number of Horses</th>
<th>Number that Developed Contralateral Limb Laminitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe unilateral laminitis</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Puncture wound with sepsis of navicular bone, bursa,</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>joint, or DDFT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal limb amputation</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Comminuted fracture of (P1) treated conservatively (cast only)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Complete rupture of (SDFT)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Catastrophic rupture of suspensory apparatus</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>86</strong></td>
<td><strong>2 (2.3%)</strong></td>
</tr>
</tbody>
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DDFT, deep digital flexor tendon, P1, first phalanx, SDFT, superficial digital flexor tendon.
The device was used in 13 horses that underwent limb amputation for severe injuries or infections. Several other cases had already developed some degree of laminitis in the supporting limb prior to amputation and were, therefore, excluded from the study group. The 13 horses were each fitted with the support device at the time of amputation.

Only 1 in 13 developed laminitis in the contralateral limb. That case involved a heavily pregnant broodmare with a catastrophic injury, which necessitated amputation of the left forelimb below the carpus. The supporting foot was very weak, with a thin, dropped sole, a full-thickness toe crack, and severe dishing of the dorsal hoof wall. Laminitis developed in that foot 3 wk after amputation, despite the use of mechanical support. The mare was kept comfortable using a transcortical cast on the laminitic limb until she delivered a healthy foal. The mare was then euthanized at the owners' request, because they did not want the responsibility of managing an amputee. This case highlights the importance of the structural integrity of the supporting foot.

The other horse in the study group that developed contralateral limb laminitis was an athlete, who suffered catastrophic rupture of the suspensory apparatus. The horse developed radial nerve paralysis in the supporting limb after general anesthesia and, although the etiology is unclear, subsequently developed laminitis in that limb. In the 37 cases of severe unilateral laminitis, each horse underwent venography, palmar or plantar realignment of P3, and DDFT in the laminitic limb in addition to application of mechanical support on the contralateral foot. All 37 horses remained free of laminitis in the supporting foot.

4. Discussion

The most effective means of preventing contralateral limb laminitis is to prevent overloading of the supporting foot by successfully managing the primary problem. However, because prompt resolution of a non-weight-bearing lameness often is impossible, the key to minimizing the risk for contralateral limb laminitis is to support the weight-bearing foot in a way that maximizes laminar perfusion. Because blood flow to the laminae of the dorsal hoof wall is compromised as soon as the weight-bearing foot is under constant load, the sooner the support device is applied, the greater the likelihood of preserving laminar integrity and preventing laminitis in that foot.

Laminar damage in the supporting foot likely begins within a few hours of constant loading. However, the severity of lameness in the injured or diseased limb often masks signs of a problem in the supporting limb for weeks after initial injury. This fact too often gives the clinician a false sense of security concerning the supporting foot: "if the horse is not showing signs of discomfort, then there is no problem".

Unfortunately, signs of laminitis in the supporting foot often do not become apparent until the horse is sufficiently comfortable on the injured limb to begin bearing some weight on that limb or until pain in the laminitic limb is more severe than the pain in the injured limb. By that time, laminar changes in the supporting foot are well advanced. The horse is then in danger of overloading the injured limb to spare the now more painful laminitic limb, creating a destructive cascade of deterioration.

The timing of the clinical manifestations of contralateral limb laminitis, typically around 3–6 wk post-injury [2], may also be explained by the sequence of events associated with laminar degeneration. In experimentally induced laminitis, necrosis of the primary dermal layers may not occur until approximately 40 days after induction of laminitis. This time frame corresponds with the recurrence of pain seen in many clinical cases of laminitis and is attributed to digital sepsis and necrosis [1].

Although fitting a mechanical support device to the weight-bearing foot can be a challenge in a horse with a non-weight-bearing lameness, it is not impossible and the benefits far outweigh the potential risks and practical difficulties. Attempting to correct the problem once the horse is showing signs of discomfort in the weight-bearing foot is an uphill battle that is too easily lost. The reported mortality rate in horses with contralateral limb laminitis is at least 50% [2]. Preserving the "good" foot must be made a priority when managing horses with non-weight-bearing lameness if a satisfactory long-term outcome is to be achieved.

Cases that do not go to surgery for several days after injury or that must be shipped to a surgical facility for treatment are at very high risk for contralateral limb laminitis. The clinician should make every effort to apply mechanical support to the weight-bearing foot as soon as possible, ideally within a few hours of the initial injury. Applying the device days or weeks after injury may be too little treatment too late in the development of the injury. Ideally, every training facility and equine ambulance vehicle should have a sling and a lifting device for such emergencies. When it comes to laminitis, prevention whatever it takes is far more effective, and ultimately less expensive, than treatment.

Contralateral limb laminitis itself should also be considered an emergency, and aggressive treatment should be instituted as soon as clinical suspicion arises. As most cases of contralateral limb laminitis involve distal displacement (sinking) of P3 [2], successful management requires considerable expertise. Preventing contralateral limb laminitis is thus well worth the effort.

The critical test for this mechanical support technique is its use in horses with unilateral non-weight-bearing lameness that persists for several days or weeks. As shown in Table 1, less than 2.5% of such horses developed contralateral limb laminitis
when the support device was correctly applied and maintained. There are no reliable figures available for the overall incidence of contralateral limb laminitis in horses with these types of problems, but clinical experience indicates that the figure is well above 10%.

In conclusion, contralateral limb laminitis can be prevented in the majority of at-risk patients by mechanically supporting the weight-bearing foot in a way that preserves laminar perfusion during full loading. Effective mechanical support is comprised of (1) raising the heels and setting the functional break over point back far enough that the horse preferentially stands with a palmar angle of at least 20º and (2) providing arch support. To be most effective, the device must be applied at the onset of lameness and maintained until the horse is able to bear full weight on the injured or diseased limb.

The author is the principal developer of the Modified Ultimate and a shareholder in Nanric, Inc.

Footnotes
[a] Nanric, Inc., Versailles, KY 40383.
[b] Dormosedan®, Pfizer Animal Health, West Chester, PA 19380.

References

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