While flags might not have flown at half-mast on Monday to lament Barbaro's death, news of his death hit people around the world with an emotional gut punch. We've been pulling for the courageous colt's recovery since May 20, 2006, when he shattered his right hind leg running in the Preakness Stakes. We've cheered his progress and prayed during his setbacks and war with laminitis. No other injured equine athlete has remained in the public eye for so long, and now his run is over.

Barbaro's death might lead one to think that despite the best veterinary care available, horses with severe leg injuries and/or laminitis are unrecoverable and should be immediately destroyed. But one equine veterinarian says that couldn't be further from the truth--that horses with "catastrophic" injuries and/or laminitis can often be saved, even when all appears to be lost.

Ric Redden, DVM, a veterinarian, farrier, and founder of the International Equine Podiatry Center in Versailles, Ky., has a lot of experience with tough cases like Barbaro's. As a pioneer in the field of equine podiatry, he deals daily with fractures, laminitis, and a host of other hoof problems that cause lameness. He says there are two keys to winning against laminitis--immediate, aggressive action when a horse is in the early stages or is at risk of laminitis, and using venograms to assess and monitor blood flow in the foot.

The Challenges of Laminitis

Laminitis is an often-devastating disease of the equine foot that occurs in response to many different factors, including carbohydrate overload (such as when a horse gets into the feed room and pigs out), systemic disease (such as colic or colitis), and mechanical overload (as in Barbaro's case, when one or more limb must carry much more weight than usual). Whether toxins in the bloodstream or simple overload cause the problem, the result is the same--weakening of the laminae (interlocking Velcro-like tissues) that hold the horse's hoof wall onto the third phalanx bone in his foot.

Once the laminae (the Velcro-like connections) are weakened, the weight of the horse coming down through his bones will tear the laminae. And once they begin tearing, the remaining laminae become even more overloaded, resulting in more tearing and ultimately sinking or rotation of the bone in the hoof. Unchecked, the horse's weight can drive the bone through the sole of the hoof.

As you can imagine, this instability is extremely painful for the horse. Treatment for laminitis has always been complicated, largely because you can't put a horse in bed until his feet heal as you would a human with a foot problem. As prey animals, horses are not physically or mentally designed to lay down for long periods of time. So the horse's weight (around 1,000 pounds for the average light-breed horse) pushing on damaged laminae creates a major mechanical obstacle to healing. Swelling in the damaged laminae compromises blood flow, which is desperately needed to bring nutrients to the damaged tissues--without it, they will not heal.
Laminitis strikes with varying intensity, and levels of recovery are equally varied. Some horses recover completely; many recover to pasture, breeding, or light exercise soundness. A few can't be saved. Redden says the latter category continues to shrink, and that quick action, aggressive mechanical support, and maintaining adequate blood flow can save many more horses.

**Don't Wait for Rotation**

Traditionally, one thing veterinarians have looked for when diagnosing laminitis was downward movement or rotation of the tip of the third phalanx bone within the hoof on a radiograph. However, Redden says this approach is missing the boat.

"Even when there is a very small amount of rotation, that means the bone is unstable and the vascular (blood) supply has already been grossly changed," Redden says flatly. "The vascular changes you can see on the venogram will be very obvious days or weeks prior to seeing bone movement on a radiograph. You don't want to see that bone change! You want to catch it before then."

In the case of contralateral or supporting limb laminitis (affecting one front or hind limb when the other is bearing all the weight, as with Barbaro when his right hind leg was fractured), Redden says, "Once that bone starts moving, they crash because the trigger mechanism is the other limb. It's not like you have a single dose of carbohydrate and one trigger. Your trigger is going on every day. Once it starts, they crash and sink (a more severe manifestation of laminitis where a horse's third phalanx bone detaches from the hoof capsule all the way around and sinks straight down through the hoof, rather than the bone rotating at the toe). Every contralateral limb laminitis case I ever saw was a sinker."

In other words, success lies in preventing the problem, because handling it once it begins is much more difficult. Supporting the at-risk limb before problems develop and monitoring its health constantly as well as that of the injured limb is paramount, Redden says.

**The Value of Blood Flow**

"With catastrophic injuries, what decides whether a horse is euthanized or goes to surgery? Loss of vascular supply," says Redden.

Blood flow is critical for healing any tissue--cut skin, broken bones, or damaged laminae in the hoof. Several years ago, Redden collaborated with Dr. Chris Pollitt of Queensland, Australia, in the early 90s to develop a technique for evaluating blood flow in the living foot called a venogram. It consists of injecting contrast media (which will show up on a radiograph, or X ray) into the digital vein with a tourniquet over the fetlock, which allows retrograde filling of the arterial system via the capillaries. Then a radiograph is taken to see how well blood is flowing through the vessels of the foot.

**VENOGRAMS TO SEE BLOOD FLOW**
(Above left) Normal venogram, 5-year-old Arabian mare. This lateral (from the side) venogram (radiograph of foot with contrast media injected into the blood vessels) shows the information that an equine podiatrist can gain from this procedure.

(Above right) This mare has high-scale laminitis. She has a rectangular area of contrast pooling at the dorsal (front) aspect of the coffin bone (blue oval) where the integrity of the dorsal laminae is compromised (acute laminar leakage). Also, there is a stark loss of contrast in the entire palmar zone (yellow oval), and loss of contrast in the heels due to excessive loading with this wedged shoe. At the coronary band, the vessels are truncated (red circle), indicating a lack of vascular supply within the foot capsule. These findings show that she is actually a sinker. The coffin bone is no longer stable within the hoof capsule, the blood vessels are compressed, and contrast pools in the space where the dorsal laminae are disrupted. This high degree of damage requires aggressive treatment with realignment and deep digital flexor tenotomy; this will provide some hope of success with a case like this.

PHOTOS COURTESY DR. AMY RUCKER

Like anything, venograms take practice, he says. "Technique error can create a confusing image for those who have not mastered the technique and developed interpretation skills," he warns. "For example, tourniquet failure will allow too much contrast media to go up the limb and create an image that can be misdiagnosed as pathological loss of blood supply. That's the biggest technique problem out there. You need lots of practice with these things. I am happy to share my experience and help veterinarians interpret these venograms." (Veterinarians can contact Dr. Redden via his website at www.nanric.com.)

With proper venogram technique, a veterinarian can see where blood flow is compromised due to damage, swelling, or poor hoof structure, and thus decide what mechanical support and/or surgery he needs to provide in order to restore blood flow to those areas.

"If the foot stays ice cold for several days (because of no blood flow) and is then revascularized, the hoof capsule falls off," says Redden. "It's like a frostbite reaction--when blood rushes back into those
dead tissues, fingernails fall off (with frostbite), and laminae explode and the hoof falls off (with laminitis).

In a horse, even if the blood deprivation only affects part of the hoof, that's the part of the hoof that will die if blood flow is not restored. When it dies, it can't bear weight, and it stresses the rest of the hoof by not doing its job. That's why knowing about any compromise of blood flow as early as possible is so critical, says Redden.

"I'll perform a venogram on all high-risk feet (such as Barbaro's initially uninjured hind foot) at the first opportune time to set a baseline (evaluate the initial vascular condition of those feet)," he explains. "Then I'll do followup comparative venograms every few days depending on the case and duration of injury to see if my mechanical device is adequate (more on mechanical shoeing in a moment). I hope to at least maintain, or improve, the (vascular) pattern I saw on my baseline. If there is not improvement, I'll use more aggressive mechanical technique. Options for mechanical treatment range from simple four-point trimming or shoeing for mild chronic cases, on up to full wall ablation (removing the entire wall) on a very severe case. It's all about how much circulation is left to put this foot back together. That's what determines what you need to do, how quickly it must be done, and how well it will work."

How do you improve blood flow within a horse's damaged foot? It's a matter of knowing the forces at play in the foot and how to change them.

**Forces in the Foot**

There are five major forces at play in the equine hoof when the horse is standing:

- **The horse's weight** pressing down the column of bones in the horse's limb (gold arrow);
- **The upward ground reaction force** that counters the horse's weight (red arrow);
- **The rearward pull of the deep digital flexor tendon** running down the back of the limb and attaching on the bottom of the third phalanx bone (green arrow);
- **The laminae** holding the third phalanx forward against the hoof capsule, against the pull of the deep digital flexor tendon (blue arrow); and
- **The forward and upward pull of the extensor tendon** running down the front of the leg and attaching to the top of the third phalanx bone (purple arrow). It plays a role in extending the leg and counteracting the pull of the deep digital flexor tendon, but it is not a major force compared to the strength of the laminae, says Redden.
Normally these forces are all in balance and the bone stays in place within the hoof capsule. But when the laminae are weakened, they can no longer completely balance the pull of the deep digital flexor tendon.

"My theory is that when the deep digital flexor tendon is pulling back and the laminae are stretching, it's like a Chinese handcuff or finger-pull--the more you pull, the tighter it gets," Redden comments. "The tension forces blood out of the laminae under maximum stretch. If you can relax them, you'll get blood in them, but if you load (pull on) them, the blood goes away. I see it on the venogram.

"So when a horse is standing on one (front or hind) limb all the time, resting an injured limb, that foot's at risk for laminitis because its laminae are always under load," he explains. "They don't get any blood, so they're starved for oxygen and nutrients for a long time and they die."

"When a horse has a catastrophic injury and he keeps moving around the stall, we think he's not taking good care of himself," he notes. "But he's actually taking very good care of himself because he's keeping his feet perfused (stimulating blood flow). These horses usually show no signs of contralateral limb laminitis. On the other hand, the 'smart' horse standing there behaving for hours not moving--his supporting foot has no blood in it."

**Mechanical Advantage**

Luckily, Redden has more than two decades of experience in manipulating the mechanical forces affecting various hoof structures in order to increase blood flow and accelerate healing.

"The idea from the get-go is to provide the horse with maximum mechanical aid to support the damaged blood vessels that put the horse at risk," Redden explains. "You need a device (shoe) that will reduce tension on the deep digital flexor tendon; this will maintain perfusion of the dorsal (toe) laminae and blood vessels under the bone," he says.

To measure the shoe's effectiveness, he looks at several measurements on a radiograph, particularly the following:

- **Sole depth** (SD, pink arrows showing the distance between the bottom of the tip of the third phalanx and the sole surface);
- **Palmar angle** (PA, green lines showing the angle the bottom of the horn-lamellar zone (18 mm) makes with the shell of the hoof).

This image depicts the measurements Dr. Redden uses to evaluate and treat a laminitic horse, and to design the preventive shoeing package the horse needs.
third phalanx bone makes with the ground surface of the hoof). This horse has a negative 7-degree palmar angle.

- **Digital breakover** (DB, purple line showing the distance along the ground from the tip of the third phalanx bone to the forwardmost point of contact between the shoe and the ground).
- **Horn-lamellar zone** (HL zone, red arrows showing the space between the face of the coffin bone and the outside of the hoof wall).
- **Coronary band-extensor process** (CE, blue vertical line showing the distance between the top of the extensor process of the coffin bone and the top of the wall at the coronary band).

"The value of knowing what these parameters are at the initial onset of disease and during the progression of disease is knowing the interrelationships between them," Redden explains. "If one changes, they all change."

His initial goal is to enhance the healing environment by aiding reperfusion in compromised areas. In turn, the horse grows greater sole depth (which supports the bone) and as the foot begins healing, this reduces pain.

He starts by raising the horse's palmar angle (raise the rear of the third phalanx bone) until the deep digital flexor tendon is no longer taut and can be moved with finger pressure. Usually this means a palmar angle of around 20° (healthy palmar angle for a front foot is 3-5° and for a hind foot is 3-5° for Thoroughbreds and 5-8° for warmbloods, although there is some variation between breeds), he says. Another key is to put the horse in a shoeing device that moves digital breakover far back behind the toe of the hoof and wedges to raise the palmar angle. The breakover allows the horse to rock his foot to whatever angle makes him most comfortable. Changing that angle as his weight shifts means his foot's circulation gets "massaged" on a near-constant basis.

"Consider those measurements so you know whether your device works or not," he warns. Once the horse is shod to these specifications, he'll continue to do venograms every few days to make sure the blood supply is improving.

"If I lose vascular supply, that means my device is not adequate or is of limited use for what it's trying to do," he says. "Injury has already induced laminitis, and if that device is not maintaining circulation, that means I'm losing ground fast. Knowing that means I can intervene aggressively--use a support shoe and/or perform a deep digital flexor tenotomy (cut the tendon) *before* the horse develops clinical (visible) laminitis. I can see that on the venogram weeks before the horse will show me (with lameness) that he has clinical laminitis."

Most would consider cutting the deep digital flexor tendon a true last resort, to be done only after other approaches have been given weeks or months to succeed. Unfortunately, by waiting several weeks or months before getting aggressive with treatment, Redden says excessive damage has already occurred to the soft tissue and bone that many times is irreversible. He will do a tenotomy as soon as he sees a shoe is not working as he likes, or when the coffin bone has sunk below the circumflex blood vessels that normally run beneath the bone.
"The advantage of doing a tenotomy that early is that my mechanical device (shoe) will give me 60-70% relief of pull from the tendon, but a tenotomy gives me 100%," he explains. "That improvement of 20-30%, that's significant. That helps me stop the foot from getting worse, right now."

It's important to keep a constant close eye on these horses' feet, he says, because as the foot grows its angles will change. "It's very important to stay tuned to what's happening in the foot with regard to mechanics," he comments. "If you ignore it for four weeks and lose 10° off your palmar angle (because of the toe growing faster than the heel), you're back in the high-risk zone again."

**Supporting Limb Specifics**

When a horse severely injures one limb or hoof, "Protecting the good foot must be in your mind immediately!" Redden states emphatically, "Don't wait until there's a problem. When he gets sore four to six weeks after the injury, he's been foundering for four weeks by that time.

"With that horse that's suddenly switching his weight to his other (injured) foot, you've got your work cut out for you," he says. "You have high-scale damage. The horse is sunk or rotated and may even be penetrated (the bone may have come through the sole) before you know it, because you couldn't pick it up before to look at it.

"The prognosis for a unilateral case is very good provided that the initial limb injured is 80-90% healed (when the horse becomes lame from supporting limb laminitis)," he adds. "Once you see lameness in the supporting limb, it's been going on for weeks and you need to get real aggressive to stop it.

"If you have complications in that surgical limb when laminitis develops, the prognosis is questionable," he goes on. "The injured limb has to be stable enough to become the support limb for the next four to six weeks. If you can do that, you're home free.

"Some of these cases walk down the ladder, one foot killing the other, and others walk up the ladder," he continues. "If they take one little step down, you can sometimes bring them back. But if they take two or three steps down, then you have a major problem. Once one foot slides down, the other follows, picking up momentum. That's what happened to Barbaro."

**Fronts vs. hinds** "Contralateral hind limb laminitis has a better prognosis than contralateral front limb laminitis (because the horse carries less weight on the hind limbs)," he says. "If the horse has bilateral laminitis (in both front or hind limbs), that's twice as bad. If they have it in all four feet, that's twice as bad as that."

**Fillies vs. colts** He notes that in his experience, fillies will get contralateral limb laminitis more quickly than colts, possibly because of hormonal influences. "They'll show signs of contralateral limb problems in three to four weeks; with colts it's about five to eight weeks," he notes.

**Starting out strong** Redden says horses with strong, thick-soled feet before the onset of laminitis are at much less risk of supporting limb laminitis than horses with light soles, thin walls, and negative palmar angles. "These feet already have a compromised vascular supply and no protective package around them," he notes. "They're at higher risk simply because they have no reserve. The better-quality foot will
survive even the most devastating insult much better than a weak foot. This is a good reason to *always* maintain optimal foot health in every horse in your care. This is the essence of preventive foot care."

**Pulling Out All the Stops**

Some cases have very high-scale damage and no blood flow at all in the front part of the foot and beneath the third phalanx bone. These cases are beyond the derotation and derotation/deep digital flexor tenotomy techniques discussed earlier, Redden says. This is the third level of correction.

"To save that foot, I have to do a full wall ablation (remove the entire detached hoof wall) and pin cast (build a cast around pins in the cannon bone; the device is designed to hold the horse's weight, 'floating' his foot)," Redden says. "At this point the laminae have been gone too long and the partly detached hoof capsule is acting like a tourniquet. Swelling (from laminar injury) leads to less blood in the foot, which leads to more injury and more swelling; it's a vicious cycle. You have to get the wall off to decompress them.

"The venogram is the only way I know to clearly understand this vast range of damage to the vascular supply," he adds.

**Catastrophic Injury: The Amputation Option**

So what options do you have if the blood supply to the foot or limb is irreversibly damaged by catastrophic injury? Since blood vessel reattachment surgery is not yet practiced in horses, and no blood means no live tissue, there are two options for this kind of case--euthanasia or amputation. Losing part of a limb is a painful thought, but there are quite a few successful cases out there to give horse owners hope.

*(story continues below)*

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**SUCCESSFUL EQUINE AMPUTEES**

(Above) Gideon, a Missouri Fox Trotter stallion, continues to be
comfortable at pasture and pasture breeds his mares 12 years after amputation of his lower right hind limb due to a catastrophic fence wire incident.

(Below) Josie is very quick on her feet with a similar level of amputation performed on her right hind leg about 13 years ago.

Above photos courtesy Dr. Andrea Floyd/Serenity Equine
Below photo courtesy Dr. Ric Redden/Nanric Inc.

"All a horse wants with a prosthesis is leg length and stump protection," says Redden. "The device has to be made so it will stay on and protect the stump in sun, rain, urine, feces, mud, etc."

He refers to Gideon, a Missouri Fox Trotter stallion who suffered a catastrophic fence wire injury that left no viable tissue more than a few inches down his right hind cannon bone.

"He's still breeding mares 12 years later, and he bred the first one five months after amputation," Redden reports. "He breeds them at pasture, not even assisted.

"If someone says a horse with a catastrophic injury has no chance of healing, they might be right!" he says. "But they don't have to heal, they just need to have a viable stump. Amputation is not for everyone, but it's a tremendous option compared to a bullet."

**The ideal case** Redden thinks that racehorses with catastrophic lower limb injury would make the best candidates for amputation, although he has not yet had the opportunity to try to help one. "They're in the peak of health, they're brave, courageous, and all heart," he says.

**There's no rush** "You don't have to kill a horse when he twists his leg off," states Redden. "Put him in a protective device and take a few days to consider the options. Move him to a facility where it can be done properly and all options can be examined, in a positive environment like a veterinary hospital. (Don't make the decisions) in the muck pit, not in the ambulance, not in the stall while the horse is trying
to cool out. When all that happens, the goals of the client and financial commitment can be considered. Don't make a rushed decision because things look hopeless.

"Consider all the options before you decide that euthanasia is the best option," he recommends, noting that euthanasia is a last resort for him and never his first choice.

**Take-Home Message**

Laminitis is an ugly disease, and surviving it is no picnic. Treatment is often not pretty, it's expensive, and the horse's survival is far from guaranteed. But the chances of success and future soundness, even with difficult supporting limb laminitis cases like Barbaro’s, go way up when laminitis can be prevented (ideally) or caught early and treated aggressively, says Redden. All these horses ask is that you give them a chance.

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**More information:**