What's one big difference between a successful surgery and an unsuccessful one? Accurate knowledge of the problem, and a plan for treatment based on that knowledge, before the patient ever hits the surgical table. The same can be said of treating a horse with laminitis--success depends on several factors, but an accurate knowledge of the extent of the damage within the feet and a plan for treating it is paramount.

During the recent Bluegrass Laminitis Symposium, held Jan. 25-28 in Louisville, Ky., host Ric Redden, DVM, founder of the International Equine Podiatry Center, discussed the usage of venograms to increase the success of laminitis treatment through increased knowledge of the extent of damage. A venogram is a radiograph or X ray taken of a horse's foot after contrast media has been injected into its blood vessels; as such, it allows the veterinarian to see how well blood is flowing within the foot.

When blood flow is compromised, vascular (blood vessel) damage is present and a chain of events follow, because no body structure can survive, let alone function properly, without the nutrients provided by blood flow. That's why it's so important to see where blood flow might be compromised--knowledge of the compromised areas allows treatment to be tailored to support those areas and help them heal.

"Before venogram imaging, radiographs were the only images used routinely to evaluate laminitis and other foot disease syndromes," Redden said. "Venograms have added to our knowledge of laminitis and other common foot problems, in large part because for the first time we can see the structural components of the vascular supply to the horse's foot. It will give you information you can't get any other way.

"The procedure is relatively easy, uses basic radiographic equipment, and can be performed on the standing horse," he went on. "However, it is new to most vets and even unheard of by others. It is technique-sensitive and requires extensive experience with multiple case studies to interpret. The validity of this procedure will increase with more awareness of the information provided and a general acceptance of vascular studies at the academic level."

Starting at the Beginning
"When dealing with an acute laminitis case, I perform a venogram on the very first examination, because I need that baseline to see what condition the foot is in at the time of my first exam," Redden stated. "Venograms are indicated, especially in the acute case, because you want to know what degree of vascular compromise is present," he went on. "The initial venogram is very valuable, as it may indicate only minor vascular compromise in a horse that is glued to the floor (not wanting to move because of the pain), or it can reveal stark loss of contrast throughout the majority of the hoof with a horse that appears to be only slightly lame. Either of these horses presents a very deceptive clinical picture."
He takes several views of each foot once contrast media is injected into the palmar vein, preferring traditional film over most digital units as he feels the resolution is much sharper. The following views are standard:

- Lateral (taken from the side) with the unit set to show soft tissue detail, peripheral vessels and solar papillae.
- Hard penetration lateral with grid to highlight deeper vascular vessels
- Dorsopalmar (taken from the front) with grid, to highlight the terminal arch and other vessels within the coffin bone
- Dorsopalmar soft tissue exposure to show peripheral vessels, followed by
- Late soft tissue lateral, which provides slightly more fill time that can offer useful information.

All film must be taken within 45 seconds in order to assure a sharp, useful profile and a diagnostic image, he noted.

The Healthy Foot
Redden emphasized that to understand the abnormal (i.e., laminitic) foot, one must first understand what is characteristic of a healthy foot. He described the following soft tissue parameters and venogram characteristics of a healthy foot as follows:

Healthy Measurements

- Horn-laminar (HL) zone (distance between the front of the coffin bone and the outside of the hoof wall at the upper and lower ends of the bone): 15 mm/15 mm for the average light-boned horse and varying with age and weight.
- Palmar angle/plantar angle (PA) (angle the bottom of the coffin bone makes with the ground): 3-5° for front feet, and 5-8° behind.
- Bone angle (angle the front of the coffin bone makes with the palmar surface of the foot): 50-51° is common for the majority of feet, but this angle can range from 35-60°.
- Coronary band-extensor process distance (the vertical distance between the top of the extensor process of the coffin bone and the top of the wall at the coronary band): ranges from 0-15 mm.
- Digital breakover (distance along the ground from the tip of the third phalanx bone to the forwardmost point of contact between the shoe and the ground): Varies relative to breed, age, use and shoeing package.
- Sole depth (SD): a minimum of 15 mm is required for full depth vascular supply.

Healthy Venogram Characteristics

- A dense, uniform contrast pattern at the coronary band that courses over the extensor process and along the dorsal face of the coffin bone.
- Circumflex vessels should be located approximately 10 mm below the palmar surface, bordered distally (nearer the sole of the foot) by small hair-like projections called solar papillae. These small vessels are in the same plane as the face of the coffin bone in the healthy foot with a minimum sole depth of 15 mm. "When a foot is trimmed too short, small red dots appear along the freshly trimmed sole," he explained. "Those dots are the ends of the individual papillae."
• A very dense vascular network in the heel zone, with continuous flow over the medial and lateral coronary plexus, which is visualized on the DP view. The terminal arch will fill and can be seen coursing through the body of and emerging through the face of the bone connecting the dorsal and circumflex vessels.

What the Venogram Tells You About Unhealthy Feet
Redden's insights into the value of the procedure and the information it provides come from studying more than 3,500 venograms in his exclusively foot-focused practice. Following are several of his comments on typical venogram pathology with various foot problems.

**Crushed solar papillae** "When the papillae are diminished in length or no longer exist along the palmar surface, pathology exists even though the horse might continue to train in a reasonably sound fashion," he said. "This is a common finding for many speed horses, but it is far from a healthy venogram. The horses with very short or no noticeable papillae will have extremely slow sole and horn growth, giving the farriers trying to keep them shod plenty of grief. You often see rim pads and full pads used when the sole is very shallow. The pads are protective, but the papillae and the sole must become healthy before the walls can once again be strong and durable."

**Club feet** "In a club-footed horse, the deep digital flexor tendon (DDF) pulls extra hard on the coffin bone, and the laminae end up like a Chinese finger trap, pulled so tight the blood can't get in," he said. "The toe area has little or no growth, the sole is very thin at the toe and the heel has increased growth, all the result of the excessive DDF influence.

"Venograms of higher grade club feet reveal a stark loss of contrast along the dorsal face of the coffin bone and the palmar zone under its apex, very similar to what we see with acute, high scale laminitis," he went on. "Club feet are a result of DDF contraction; the grade of the club is relative to the severity of the contraction. The blood supply to the laminae and sole corium is mechanically compromised due to the excessive DDF pull opposed by the lever action of the toe. There are many ways to reduce the DDF tension, ranging from a mild 4-point trim to a large range of shoes up to the DDF tenotomy. The DDF tenotomy is an option for treating Grade 4 clubs.

Venograms performed right after surgery reveal perfusion of the vessels as soon as the force of the tendon is eliminated. Unfortunately, in the high scale laminitis case, the blood supply to the sole and laminae requires several weeks or months to revitalize the severely compromised areas once the tendon is cut (more on tenotomies in a moment)."

Redden noted that his laminitis treatment protocol is based on the same mechanical advantage. The bottom line success with laminitis is relative to the speed and level of reperfusion, he commented.

**Contralateral (supporting) limb laminitis** "The tendon influence is also how horses founder with contralateral limb laminitis (laminitis in one front or hind limb when the other has suffered a severe injury and the horse doesn't use it to bear weight)," he added. "When the horse is putting the majority of his weight on the 'good' foot, the increased tension in the deep digital flexor tendon deprives his foot of blood all along the front of the foot and along the palmar rim. Adequately reducing the pull of the deep digital flexor tendon with a self-adjusting palmar angle of 18-20 degrees greatly aids in the prevention of laminitis (for more on this, see "Self-Adjusting
Palmar Angles for Healing Hooves," [www.TheHorse.com/viewarticle.aspx?id=9250](http://www.TheHorse.com/viewarticle.aspx?id=9250). If you perfuse the toe while they're supporting excessive load for long periods of time, the majority of high risk cases will not get laminitis. It's that simple."

**Acute vs. chronic laminitis** The laminar scars found on the venograms of chronic laminitis cases have a totally different pattern than the space caused by displacement (rotation and/or sinking) in the acute case, said Redden. "The leakage in these spaces will look like the veins of a feather when it's chronic; if the areas of leakage are bordered by contrast, it is more acute," he explained.

**Early laminitis** Redden noted that in the very early stages of laminitis (a few hours from onset), blood flow alterations might reveal only a slight change in the direction of the solar papillae. "The vascular supply often deteriorates rapidly over the next few days to weeks, which can be detected by subsequent venograms before radiographic or clinical (lameness) evidence is present," he noted. "Very subtle early changes are significant. This situation demands immediate mechanical therapy to reverse the forces at play. Reperfusing areas that are only slightly compromised goes a long way toward staying ahead of the damage."

"Using the venogram as a finely tuned monitor saves lives as the vascular changes occur days to weeks before bone displacement (rotation and/or sinking) occurs," he stated. "Traditionally we have been taught to equate the degree of damage with the degree of rotation. Now that we have a very reliable means of assessing vascular flow and soft tissue parameters, using rotation as a damage indicator is no longer valuable--it occurs so much later in the process."

"Also, several high-scale cases have revealed serious vascular displacement (movement of the blood vessels upward relative to the bone) within hours of onset, but with no bone displacement," he commented. "This is an area that research needs to take a very serious look at. I felt initially that the bone had to rotate or sink before the vessels prolapsed, but this appears to not be the case."

**Mid-scale laminitis** "The mid-scale case will have an increasing HL zone from the onset," he reported. "This zone will increase several millimeters before vertical displacement occurs. Closely monitor the HL zone!"

He also noted that the circumflex blood vessel appears tightly compressed against the bottom of the coffin bone, and reduced flow over the extensor process might be seen. This is not to be confused with horses that have very thin soles; such cases are also compressed, but for a different reason.

"This degree of vascular damage might occur within hours of this syndrome, or it might take several days to weeks of slow displacement," he commented. "Either way, it should be considered an emergency and demand great respect from the vet/farrier team. A favorable response to therapeutic aids will have an improved vascular pattern within a few days. If the horse appears clinically stable but the vascular pattern continues to deteriorate, derotation shoeing followed by a DDF tenotomy is the preferred treatment." (more on tenotomies in a moment)

**High-scale laminitis** "Once the circumflex vessels are displaced several millimeters and prolapsed above the apex of the coffin bone, very serious compromise exists," Redden stated. "Most high-scale cases will experience a rapid increase in the HL zone and the circumflex vessel
can be prolapsed well above the apex within hours to days of onset. Very serious cases that swell 10-15 mm within 24 hours will have stark loss of contrast down the face of the coffin bone and along its lower surface, and significantly diminished supply in the terminal arch. The coronary plexus will have an area void of contrast. There will also be a stark loss of contrast along the medial quarter, and the circumflex vessel will be absent in the quarter area. When there is no contrast in these specific zones, the prognosis is grave. To aid reperfusion, I decompress these areas by performing an aggressive full wall ablation (removing the entire hoof wall), applying a pin cast (built around weight-bearing pins through the cannon bone) for support, and a beginning a treatment protocol compatible with new hoof replacement.

"Once the nutritional supply to the bone no longer exists and there is no terminal arch perfusion, the prognosis is extremely grave," he went on. "Amputation of the digit is the only other option for unilateral cases that have total vascular shutdown to the soft tissue and bone." (For more information on amputation, see "Leg Amputation," www.TheHorse.com/ViewArticle.aspx?ID=4243.)

**Monitoring treatment success** "The venogram offers a reliable means of monitoring the progress of reperfusion in compromised areas," he said. "They also help explain why some cases fail to progress in a favorable fashion. Being able to correlate the altered vascular pattern with the clinical picture, growth pattern, and tissue response greatly enhances our insight for the planning and treatment stage."

**Why Tenotomies Work**
Your veterinarian might recommend cutting the deep digital flexor tendon on a grade four club foot or laminitic horse (perform a tenotomy) to eliminate its pull on the damaged bone and laminae, respectively, giving them a chance to heal. Redden has been a pioneer of the technique, and said he has learned that optimum results are obtained by realigning the load surface of the coffin bone (the palmar angle), referred to as derotation, immediately prior to cutting the DDF.

"This can be technique-sensitive when there is little or no heel that can be removed," he noted. "My goal is to establish a zero-degree palmar angle with the ground surface and a minimum of 20 mm of space between the palmar rim of the coffin bone and the shoe's upper surface, using a 3-5° rail shoe with a heel extension to prevent toe lift after the tendon is cut.

"Failure to reposition the coffin bone has limited success as the sole area beneath the apex of the coffin bone continues to be mechanically impaired," he warned. "The reduced strain on the laminae and downward load on the inner sole allows blood to perfuse (spread into) both the laminae and sole, as the bone is no longer pressing its tip so tightly against the sole. This protocol, performed in a timely fashion, can save the lives of a large majority of high-scale cases."

As he showed venograms from a high-scale club foot case before and after tenotomy, he commented, "This is exciting stuff! Look at the vascular supply along the dorsal face of the coffin bone and palmar zone that was not present before the tendon was cut. The mechanical effects of the DDF on digital perfusion are tremendous. The data obtained from digital venograms is the foundation of evidence-based medicine that has greatly enhanced our ability to successfully treat laminitis."
Problems With Venograms
As should be apparent by now, a venogram is not a simple yes/no test. Errors in technique can result in venograms that look worse than the horse's true status, and a practiced, trained eye is needed to read them. Redden described several technique errors that can lead to inaccurate venograms; for more information on this topic, see "Interpreting Venograms and Artifacts" by Amy Rucker, DVM (www.TheHorse.com/ViewArticle.aspx?ID=4249).

Take-Home Message
"Horses are very durable, and they'll lie through their teeth about how they're feeling," Redden concluded. "Do not depend on the horse to tell you how healthy the laminae are. Depend on your venogram."