Foot / Lameness

BY NANCY S. LOVING, DVM, AND CHRISTY WEST

Therapeutic Shoeing

The AAEP table topic on Therapeutic Shoeing attracted a large group of veterinarians and farriers as Steve O'Grady, DVM, MRCVS, of Northern Virginia Equine, and Bruce Lyle, DVM, a veterinarian who focuses on foot care in Aubry, Texas, led a discussion sparked with controversy.

Questions began instantly, with the first topic focusing on treatment of hind limb suspensory desmitis. There was little debate that the feet and sore suspensory ligaments (SL) are related to one another. By managing the feet in a logical approach, O'Grady believes that suspensory ligament problems will improve. He feels the only way that shoeing directly affects a hind leg suspensory ligament is related to length of the foot and ease of breakover. He advocates shoes that are as wide as they are long, with no extended heels. He doesn't feel that raising the heels is helpful, particularly if the entire back of the foot is "crushed" and collapsed.

For suspensory ligament desmitis, Lyle advocates the use of rail shoes when the plantar angle (the angle of the base the hind coffin bone makes with a horizontal plane) is zero or negative. A rail shoe is a square-toed shoe with "rails" along the underside of the shoe. He feels many superficial digital flexor and suspensory ligament problems are a result of delayed or inadequate function of the deep digital flexor tendon during the stance and propulsion phase of stride. He commented that a negative palmar/plantar angle of the coffin bone ends up stretching the deep digital flexor tendon to a less-than-optimal state for support and contracture. His approach is to use the rail shoe to move the horse's weight back onto its heel since typically lameness moves weight toward the toe. His objective is to engage the deep digital flexor tendon to take tension off the suspensory ligament.

In practice, he has noted that improvement of the palmar/plantar angle can transform a previously lame horse (or one that is reluctant to perform) into a sound horse.

Veterinarians in attendance all agreed that it is not always in the horse's best interest to make his foot "look" better, especially if the horse has adapted to its unique situation.

An audience participant pointed out that most therapeutic approaches are an attempt to return weight-bearing back to normal; for example, a navicular horse lands on its toe so it is important to move weight loading toward the back of the foot.

To compute the center of force, Lyle uses a tool called a Mat*Scan (Tekscan, Inc.) that records ground reaction forces at 40 frames per second from the time the foot contacts the mat until final liftoff. His objective is to move the ground reaction forces back toward the center of the foot mass, to improve phalangeal alignment, and by doing so, to allow every structure in the foot and leg to bear its share of the load; this is especially useful to alleviate repetitive stress injuries.

Andrea Floyd, DVM, co-editor of the book, Equine Podiatry, discussed chronic heel pain in horses. She noted that radiographs often show a post-like position of the short and long pastern bones, then the coffin bone ends up sitting in a negative palmar angle, such that the horse appears to have two disparate feet. This alignment often leads to heel and quarter cracks. She stressed that trimming the hoof to the widest part of the frog does not take into account the palmar angle, and the best way to improve heel growth is to first find the center of the coffin bone on radiographs. Then draw a straight line down to the distal bearing surface and rasp the cranial-dorsal portion of the hoof into a zero palmar angle. This leaves an invisible heel area to be filled with a flat shoe applied by nailing only at the toe. Soft Equithane packing, taped in place with duct tape, is applied between the heel and shoe and fills the "air gap," and that is left for 6-8 weeks. With this shoeing method, the heels still receive neurologic messages to remain stable and grow.

Lyle added that the position a horse stands for hoof radiographs will affect the phalangeal alignment, but the parameters within the hoof capsule relative to the coffin bone will remain consistent.

Gene Ovnicek, RMF, brought up the point that in dry climates (such as the western United States), horses grow a lot of false sole (the sole of a hoof that does not exfoliate normally), the resulting trim could end up with a negative palmar angle. He recommends using radiographs,

hoof testers, and veterinary guidance to assist the farrier in trimming the soles in feet that are difficult to read.

An audience member made several remarks, including the statement that dynamic movement can alter perception of the standing trim. He also said the impact of footfall is unique to each horse, and reminded the audience that a standing shoe is not always the same as a moving shoe, nor does a horse in rehab need the same support as an athletic horse.

O'Grady remarked that the soft tissues of the foot bear weight and serve to dissipate concussion. He said the horn wall needs to come back to the base of the frog to encapsulate all the structures for support. O'Grady cautions against trimming away frog as he feels that this would alter the base of support, and problems develop if the frog sits below the heels or is receded. Lyle pointed out that even 1 mm of trim can make a huge difference to a horse's comfort, especially when the foot is trimmed by 5-10 mm and there might only be 10-12 mm depth beneath the coffin bone.

He also said there is a misconception of trimming to the widest part of the frog: If there is not enough depth of foot, then there isn't a sufficient amount with which to work. Additionally, trimming heels can move the center of force sufficiently forward to put the weight of the horse on the navicular bone and deep digital flexor tendon/bursal unit, resulting in problems ranging from bursitis to necrosis and rupture of the tendon. If there is only 3-5 mm thickness of sole based on radiographic measurements, the horse needs time to grow foot. A trim job should attempt to maintain at least 15 mm of sole depth; at sole depths of 6-7 mm or less, one should worry about bruising and lameness. If the sole is too thick with false sole, the resulting trim could end up with a negative palmar angle.

Lateral radiographs are helpful for the farrier and veterinarian. O'Grady stressed that lateral-medial hoof balance is also important and the length of heel from the ground to the hairline should be similar side-to-side. Radiographs taken of the dorsal-palmar view help evaluate balance, particularly when using a measurement taken across the heels over the wings of the coffin bone. If a balance abnormality is present, one must determine if it is related to a horse's conformation or is farrier-induced sheared heels. Usually a horse that lands laterally will rotate the foot to land on the inside, and this must be corrected.

The question was asked about how to differentiate a laminitic horse from a thin-soled horse? The unequivocal answer from the moderators was: "Treat as if laminitis until proven otherwise." Sequential radiographs provide objective measurements for monitoring the bone to hoof capsule relationship. For a reference on each individual horse, compare the hoof capsule thickness just below the extensor process to thickness at the level of the tip of the coffin bone. Both should be equidistant and approximately 15 mm thick.

Another question was: What is normal foot landing? The speakers said ideally a horse lands flat or heel first, but it should be considered that we don't know if some horses are just fine hitting toe first. Lyle noted if the horse has 6 mm digital breakover and joint articulation lies in the center of the coffin bone, then this horse is likely to have a long, sound career. If the horse has a 2½ inch (65 mm) digital breakover and articulation is in the caudal one-third of the foot, he is not likely to stay sound landing toe first.

In summary, everyone agreed that it is not always in the best interest of the horse to make his foot "look" better, especially in a horse that has adapted to its unique situation. Additionally, all parties were in favor of the idea that more critical biomechanical research with an eye to the details and factors discussed would add benefit and

greater consensus as to therapy and prevention.

Managing Acute and Chronic Laminitis

To a packed room of veterinarians at the 2007 American Association of Equine Practitioners Convention in Orlando, Fla., Jim Belknap, DVM, PhD, Dipl. ACVS, an associate professor of veterinary clinical sciences from The Ohio State University's Galbreath Equine Center, and Rob Boswell, DVM, a practitioner with Palm Beach Equine Clinic in Wellington, Fla., opened the table topic discussion about prevention and treatment of laminitis.

Belknap (who co-hosted TheHorse.com's Webinar on Understanding Laminitis) said the latest research points to laminitis as an intense inflammatory injury of the foot, and it is no longer believed to be solely a blood flow problem. It is known that even though a horse with imminent laminitis might look normal and show no lameness, inflammatory mediators are already elevated by up to 1,000-fold in the laminae.

With that in mind, Belknap is an advocate of very high levels of anti-inflammatory medications (500 mg three times per day of flunixin meglumine, or Banamine) within the first 72 hours of insult (a cause of laminitis) or onset. He said he realized this high dose is more likely to lead to some gastrointestinal (GI) ulceration and, thus, it should not be used on every horse. But he stressed that it is critical to get foot inflammation under control, so ulceration might be the lesser of two evils. Once the acute stage has settled down, it might be desirable to switch to phenylbutazone for better pain relief.

Ice might be beneficial for the same reason that hypothermia is used in some types of inflammatory injury in human medicine: hypothermia is anti-inflammatory and slows the metabolic rate (i.e., enzyme activity) of injured tissue. There could be great benefit to immediately ice the feet to decrease activity of deleterious enzymes such as matrix metalloproteinases and to decrease inflammation. Studies show the best means of cooling the feet is by using a bucket arrangement or wrapping the hoof in a 5-liter plastic bag or truck tire inner tube filled with ice and water. Refresh the ice continually as needed. The discussion facilitators stressed that no harm can come of keeping feet in ice for 72 hours--as much ice therapy as possible is desirable in averting the inflammatory effects related to acute laminitis. After 72 hours, no ice is necessary and, in fact, it might be counterproductive by softening the foot too much. The horse should not be walked during the acute phase.

DMSO (dimethyl sulfoxide) is a commonly employed drug for laminitis treatment, but there is very little research supporting its use. In an already-laminitic horse, DMSO might have anti-inflammatory properties due to its being a superoxide radical scavenger (it binds to radicals and inactivates them), and it might work as a vasodilator. It can be given either orally or intravenously (IV) with good absorption.

Equioxx is a new non-steroidal anti-inflammatory drug (NSAID) that targets COX-2 inflammatory mediators. Belknap advised that this drug needs five to seven days to reach a steady state of effect, but if it's initially given at a triple dose, the steady state can be reached in 24 hours. Until scientists perform research on its effect in the early stages of laminitis, it might be best used on nonacute cases due to concerns about its potential to exacerbate vascular events (such as Vioxx did in humans at risk) in the at-risk horse or in the acute case of laminitis.

Equioxx should be advantageous in chronic cases, as there should be fewer side effects due to a lowered incidence of GI ulceration or kidney lesions when compared to other NSAIDs. However, it was also mentioned that COX-2 mediators are needed to heal gastric ulcers, so there is some concern on giving the drug to horses known to have GI ulcers.

Blood flow might not play as predominant a role as once thought, so vasodilator therapy is not necessarily as important as some other treatment choices. Acepromazine only opens vascular beds for about 40 minutes following intramuscular (IM) administration, so if given, it should be administered at least four times a day. Another possible vasodilator to use is IV lidocaine.

Belknap and Boswell said they felt a single dose of dexamethasone in a horse at risk of laminitis might help decrease inflammation in the feet, but the vets are resistant to use it due to potential litigation regarding steroid use and laminitis.

Supporting the Hoof

The facilitators and audience discussed foot support. Boswell prefers a two-part putty mixture material placed generously from the tip of the frog to the back of the frog and into the sulci (grooves in the sides of the frog). This recruits the frog and the sulci for support. There was mention that "Soft-Ride" pads give a horse with acute laminitis a good measure of relief, but these pads only contact the frog, so it helps to also use impression material within the sulci.

Lidocaine nerve blocking of the front feet on the initial visit allows assessment of any hind limb involvement, shoe removal, and radiographs. Belknap suggests that veterinarians use lidocaine for the nerve block due to its short duration of action. Shoes left in place could place too much pressure on the hoof wall and laminae. Removal of the shoes also allows the practitioner to obtain good X ray images to evaluate the internal components of each hoof. Prognosis of foot health and integrity is achieved by comparative views of radiographs (both lateral and D-P, or dorsopalmar, views) taken during the initial 35 days of a laminitis event. Measurements of the distance from the dorsal hoof wall to the dorsal border of the coffin bone assist in evaluating the integrity of the laminae within the hoof capsule and helping determine if there is any displacement or rotation of the coffin bone.

Boswell suggests serial weekly radiographs for four weeks. If there is a 25-30% decrease in sole depth during this time, this is not considered a good prognosis and the laminitis is likely terminal. If there is less than 6-7 mm of sole, treatment might fail to alleviate the crisis. If a horse is not progressing well despite aggressive therapy, a venogram might be helpful to determine the circulation in the front of the hoof. If circulation is absent, euthanasia might be indicated. However, not all veterinarians agree, and it was stated that some horses have been saved that appeared to have no chance on venogram results.

If the shoes are left on, the back of each foot should be filled with cushion support substance (such as two-part putty) from the tip of the frog to the back of the foot. The hoof should be placed on the ground so the material fills the spaces within the frog and any extra oozes out that would have caused excess pressure.

In the early stages, a horse undergoing rotation can be placed in a temporary raised-heel shoe, such as the Nanric

Ultimate (taped on), but both practitioners recommend unscrewing one wedge from this shoe to make it shorter in horses whose coffin bones have both rotated and undergone sinking. The objective is to stabilize and derotate the coffin bone as much as possible to relieve forces, while providing support to internal structures of the foot. Both clinicians emphasized that it is important to watch the horse's response to shoeing, and they should realize that there is not one type of foot support that works for every horse.

The discussion continued onto chronic laminitis, noting that an affected horse has a mechanical problem that can't be fixed chemically by this point in the disease. The best approach is using special shoes.

Audience discussion centered around the wooden clog shoe, using either a homemade shoe made of 1-1/8" plywood, beveled 45 degrees all the way around, or the commercially available EDSS (Equine Digit Support System) product. These are screwed in on the side of the hoof wall, and just enough cushion impression material is placed in the frog area to give relief without too much pressure. Such a shoe absorbs concussion and allows the horse to adjust how he wants to stand, possibly more so than with other shoeing options. Belknap and Boswell pointed out that they use many different types of shoes in the chronic cases, and one shoe does not work on all cases.

Belknap has noticed that previously 10% of laminitis cases were in horses with pasture-associated obesity; now this has increased to 60-70% of cases. He cannot find an explanation for that trend, nor did anyone in the audience have any suggestions.

Wooden Shoes for Chronic Laminitis

The chronically laminitic horse is often a very tough case to manage because displacement of the coffin bone within the foot leads to a lot of pain and damage, in addition to the damage that allowed the displacement in the first place. O'Grady, discussed how to build and fit wooden shoes (clogs) to improve healing in three forms of chronic laminitis.

He listed several benefits of these shoes, which are made out of stacked plywood or subfloor wood:

- Easy to build;
- Lightweight;
- Dissipate energy (absorb shock) better than harder metals;
- Inexpensive;
- Flat, solid construction allows weight bearing to be applied over specified sections of the foot;
- Easily altered according to the horse's needs;
- Applied nontraumatically (no impact from nailing, as they're attached with screws).

A thorough assessment of the foot with lateral and dorsopalmar radiographs (side and front views) is essential to design the shoe according to what that foot needs, he noted.

When the shoe is constructed from a wood block, the sides and toe are cut at about a 45° angle. This places weight bearing directly under the bones, allows the horse to easily choose the most comfortable hoof angle when standing, and decreases torque on the laminae (which attach the coffin bone to the hoof wall). The shoe can be further modified in several ways: Its foot surface can be "routed" out in specific areas to alleviate pressure on a dropped sole, wedge pads can be added to further elevate heels, and the overall thickness of the shoe can be modified by adding or removing layers of wood.

O'Grady went on to describe the use of this shoe for three manifestations of chronic laminitis: dorsal rotation (the most common rotation case), medial or lateral displacement of the coffin bone (sinking on the outside or inside of the foot), and dropping of the sole or prolapse of the coffin bone through the sole.

Dorsal rotation In these cases, the coffin bone has pulled away from the hoof wall at the toe and is rotating so its tip is closer

to the ground. O'Grady recommended realignment of these feet so the bottom surface of the coffin bone is parallel to the ground by removing some of the heels and using the increased solar surface for weight-bearing. Once the foot is prepared, impression material is applied to the foot to recruit the sole, bars, frog, and sulci (grooves alongside the frog) for weight bearing. Then the wooden shoe is applied with 1 1/2-inch drywall screws.

O'Grady said that in some cases of coffin bone rotation and prolapse (penetration through the sole), this treatment has provided a viable alternative to deep digital flexor tenotomy (cutting the deep digital flexor tendon). He reported a favorable response (increased sole depth and wall growth at the toe) in 17/21 cases (81%) with this method.

Medial/lateral sinking Medial sinking (to the inside of the foot) is more commonly seen, although sinking to the outside has been noted in supporting limb laminitis, O'Grady reported. The approach for these feet is similar to that for dorsal rotation, except the heels might not need to be taken down to realign the foot, and a one-quarter-inch extension on the high side is used to help lighten the load on the low side.

He found a favorable response (increased wall growth on the low side) in 8/11 cases (65%) with this method.

Solar/coffin bone prolapse In these tough cases, the coffin bone is realigned as with the dorsal rotation case, heel elevation is used to decrease the pull of the deep digital flexor tendon, and the shoe is routed out to prevent weight bearing by the prolapsed sole and/or bone. The rear half of the foot is packed with impression material to help support the horse's weight.

He reported a favorable response (cornification of the exposed soft tissues and hoof wall growth) in 7/9 cases (77%) with this method.

"The wooden shoe provides another very consistent farriery option when treating a horse with chronic laminitis," he concluded

Dr. O'Grady says, "The wooden shoe (two examples are shown above) provides another very consistent farriery option when treating a horse with chronic laminitis."

Looking Inside the Lame Foot

Advances in diagnostic imaging such as digital radiography (X rays) and MRI have given researchers the tools they need to look inside and learn more about lame feet in horses. However, those tools require a good deal of knowledge about how to interpret the results, and those results have to be viewed in light of the horse's clinical signs.

At convention two world-renowned practitioners spent a half-day informing attendees about the proper use and interpretation of these imaging methods, reporting on recent research and a host of case studies to illustrate their findings. Sue Dyson, VetMB, PhD, FRCVS, head of clinical orthopedics at the Animal Health Trust in Newmarket, United Kingdom, and Kent Allen, DVM, owner of the imaging referral facility Virginia Equine Imaging in The Plains, Va., presented the popular session.

Dyson described the objectives of the presentation as follows: to present the results of recent studies, discuss the art and science of lameness diagnosis, provide practical tips, show some high-quality images, and demonstrate that sophisticated technology is not always required.

For example, she commented: "It is important to recognize that computerized or digital radiography does not necessarily equate with better. Excellent quality conventional radiographs can be vastly superior to poor quality digital images. Attention to detail is crucial to achieve excellent quality images, whichever technique is used. However, excellent quality computerized or digital images can potentially yield more information than conventional images and enhance our diagnostic capabilities.

"I believe very strongly that there is both art and science in lameness diagnosis," she opined. "There are rules, but there are very fuzzy edges to them."

Keep Asking the Question

Allen briefly discussed a tough lameness case that was still an enigma after extensive nerve blocks, scintigraphy (bone scan), and physical examination. When the horse's long winter coat on the leg was clipped for ultrasound, a small swelling was noted that turned out to be a large lesion in the superficial digital flexor tendon.

"That's the diagnostic clipping procedure," he said with a chuckle. "A detailed physical exam is critical to these cases. You have to keep asking the question, what's going on here? If there's no answer on scintigraphy or clinical examination and nerve blocks, either keep blocking or go back to your imaging and ask more questions."

Dyson and Allen agreed that horses with significant proximal (upper) superficial digital flexor tendon lesions like this don't tend to recover full soundness for competition-level exercise.

Palmar Process Fractures of the Coffin Bone

This term describes a fracture of the rear "wings" of the coffin bone; the inside (medial) wing, outside (lateral) wing, or both can be fractured. An Animal Health Trust study of 22 horses (eventers, show jumpers, and general purpose horses with an average age of 8.4 years) found that the medial palmar process (back part of the wing) was more often affected, accounting for 81% of fractures. Owners of many of the horses had not observed a sudden onset of acute lameness, but horses were mildly or moderately lame upon examination at the Animal Health Trust—less severe than one usually associates with fractures, Dyson noted.

She reported that lameness was worse

when the horses were worked in a circle, especially on hard ground with the lame limb on the inside. Conventional radiograph views showed no abnormalities in half of the horses, but oblique (off-angle) views were able to show the fractures. "This highlights the need for routine use of oblique projections when evaluating horses with foot pain," she advised.

She also noted that nuclear scintigraphy or bone scanning identified bone remodeling at the fracture site in all 12 horses that were scanned. Scintigraphy is a metabolic imaging modality that uses blood flow and bone remodeling to produce an image. A radioactive compound is injected intravenously and circulates throughout the horse, localizing in areas of injury and active bone remodeling. The radioactivity is measured, producing an image. "Nuclear scintigraphy can be useful to highlight the potential presence of a fracture and prompt acquisition of different radiographic views to identify a fracture," she said. However, scintigraphy is not usually essential for diagnosis.

Thirteen of the 22 horses became sound, three improved but not to complete soundness at their previous level of work, and two healed but had lameness from other injuries, for an overall successful recovery rate of 81%. Alteration of bone architecture in some horses suggested that this can be a repetitive stress injury, Dyson commented.

The location of the palmar process fracture and whether it affects the joint surface (an articular fracture) doesn't appear to affect the prognosis in sport horses, she said. However, concurrent injury of the collateral ligament that stabilizes the coffin joint might lead to increased bone instability and delayed union of the fracture.

More on the Palmar Processes

Dyson also described a study that compared radiography, nuclear scintigraphy, and MRI to evaluate the palmar processes of 258 horses with front foot pain, in part to determine if pedal osteitis (inflammation of the coffin bone) is a legitimate diagnosis. "I've always been somewhat reluctant to use (the pedal osteitis diagnosis) unless there's evidence of IRU (increased radiopharmaceutical uptake, indicative of bone remodeling, seen on a bone scan). I still ask, is it necessarily contributing to pain and lameness? I tend to say it's the diagnosis of the diagnostically destitute," she said with a grin.

Focal moderate to intense IRU was seen in 2.8% of medial processes and 1.2% of lateral ones. Radiographs noted multiple radiolucent areas (of less dense bone) in palmar processes in 21.1% of feet, new bone on the ventral (lower) aspect of palmar processes in 11.8% of feet, and palmar (rearward) elongation of the palmar processes in 4.6% of feet.

No correlation between sole depth and IRU was found, nor was there correlation between the angle of the coffin bone with the ground (solar angle or palmar angle) and IRU. Veterinarians found more abnormalities in medial palmar processes with MRI than scintigraphy, and MRI grade was significantly correlated with scintigraphy grade.

"Focal increased radiopharmaceutical uptake in a palmar process of the distal phalanx is not common, but it occurs most frequently in the medial palmar process," Dyson summarized.

"There's a huge variation in radiographic, scintigraphic, and MRI appearance of palmar processes," she went on. "Focal IRU can be seen with MRI abnormalities associated with lameness or incidental MRI abnormalities (which are present, but not causing lameness). Abnormalities are more frequent in lame limbs, but are they contributing to the abnormal loading or a consequence of it? The clinical significance of these lesions has to be established. Most horses present with concurrent lesions that could also cause lameness.

"So is pedal osteitis a legitimate diagnosis? Can it contribute to pain and lameness?" she asked. "Yes, but in no horse was this the primary cause of lameness in this study."

"So pedal osteitis is still the trashcan diagnosis?" Allen asked with a smile.

"Yes, I think it is," answered Dyson.

Enostosislike Lesions Allen described a 4-year-old Western pleasure gelding that presented with variable left front foot lameness and short striding behind. When the left front was blocked, the lameness switched to the right front. "We gave him a sound leg to limp on and he took the opportunity," Allen commented.

Imaging results were unusual in several respects, and the final diagnosis was enostosislike lesions (bone growths within the central bone cavity) in all four fetlocks. The horse was treated with shock wave therapy and tiludronate, became sound in 30 days, and he competed successfully at the Quarter Horse Congress and the World Championship Show.

"This horse had a lot of bone turnover, with osteoblastic (bone-producing) and osteoclastic (bone breakdown) processes happening at the same time," he said. "The medication tiludronate inhibits osteoclastic activity; if you can modify this process, the osteoblastic activity should also subside.

"Are these lesions always a cause of lameness? Not necessarily," Allen said. "We see these often in older horses and they're often incidental findings."

Distal Border Navicular Bone Fragments What appears to be a fragment off the distal (lower) side of the navicular bone might not actually be a fragment, noted Dyson. It might be a mineralization in the adjacent distal sesamoidean impar ligament or an enthesophyte (bony growth where the ligament attaches to the bone). Regardless of the actual structure, these apparent fragments have been increasingly recognized with the advent of digital radiography.

Dyson noted that lameness associated with movement of the fragment relative to the navicular bone can occur, and the fragments might be associated with pathology (changes due to disease) and/or adhesions of the digital sesamoidean impar ligament and/or deep digital flexor tendon.

Figuring Out Tough Cases After presenting a case where the horse's response to nerve blocks didn't entirely match the imaging results, Allen made the following comments: "The longer I do this, the more nervous I get about where local anesthetic used for nerve blocks is going. They're still the gold standard, but the anesthetic diffuses and moves around, so you can block less or more structures than you intended. Take nerve blocks at face value if all of your diagnostics are falling into place. If not, you've got more to look at."

Dyson described a similarly confusing case, with the following conclusions: "Consider the spectrum of pathology and the relationships between the cartilages of the foot and collateral ligaments of the coffin joint; they're connected, and if one is damaged, the other is likely to be as well. Learn the anatomy; you're not going to know all of it all the time because you forget things. You need to go back to the anatomy textbooks and don't be afraid to get bone specimens, preferably with ligaments attached, so you can remind yourself of the attachments of these structures to reach an accurate diagnosis."

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> DR. SUE DYSON

Sidebone The collateral cartilages of the foot serve to dissipate shock when the foot lands, explained Dyson. At ground contact, they move abaxially (away from the centerline). Ossification, or hardening, of the foot's cartilages into bone (sidebone), affects this function and is easily detected on most radiograph systems.

Several Animal Health Trust studies investigated the prevalence and severity of sidebone. One study of 268 horses graded ossification on a scale of 0 to 5, with 5 as the most severe grade. Twenty-eight horses had sidebone of some grade.

Breed, body weight, and height to body weight ratio were all significantly associated with sidebone grade. Large native ponies such as Dales, Highland, Fell, and Connemaras, along with heavier individuals, were more likely to have more severe sidebone. Height to body weight ratio was negatively associated with sidebone grade; in other words, short, heavy horses had a higher occurrence of severe sidebone.

Lateral and medial cartilages had significantly different sidebone grades, and usually the lateral cartilage grade was more severe.

"Large medial cartilages, asymmetry between feet, and a marked lack of correlation in size between the cartilages within a foot may be more indicative of an abnormality," Dyson noted.

Nuclear scintigraphy (on 186 horses) This imaging modality was useful to see the level of remodeling in the cartilages of horses with sidebone; moderate to severe ossification as seen on radiographs was often associated with IRU.

All fractures of ossified cartilages also had IRU, indicating that moderate to severe ossification is a risk factor for fractures. Dyson reported that there was "good correlation and excellent agreement between radiographic and scintigraphic grades."

She also noted that ossification of only one cartilage of the foot might result in unbalanced stresses on that cartilage and associated ligaments, possibly contributing to a greater risk of injury to that cartilage than in a foot with symmetrically ossified cartilages on both sides.

"Some fractures were not easy to define radiographically, and scintigraphy confirmed them or sent us back to investigate further and find them," she commented.

"Scintigraphy may give information about the potential clinical significance of ossification of the cartilages of the foot and associated lesions, thus, prompting further study," she summarized. "This study also verified the observation that marked asymmetry of the cartilages of the foot within a foot may be a risk factor for injury."

"I think we're getting to some clarity about sidebone," commented Allen. "For years we were told it was due to mediolateral (side-to-side) hoof imbalance, but there's more to it than that. I think it really does point out that we need to look at that sidebone in detail and make sure we're not just blasting past that lesion."

Fracture of sidebones Ten horses with 12 total fractures of the collateral cartilages were studied, and it was found that all of them had at least moderate ossification of the cartilages. Most (92%) of the fractures were at the base of the cartilage, and the medial cartilage was slightly more likely to be fractured (58% of fractures).

"Lameness tended to be most severe on a 10- to 15-meter circle on a hard surface with the lamer limb on the inside of the circle," reported Dyson. "Lameness was

abolished by palmar (abaxial sesamoid) nerve blocks.

"In some horses it was difficult to make a definitive diagnosis based solely on radiographic findings, and comparison with nuclear scintigraphic images was invaluable," she said. "Comparison of solar, lateral, and dorsal scintigraphic images was invaluable to precisely locate the site of IRU."

Associated trauma to the coffin bone Four horses with severe sidebone were found to have associated trauma to the coffin bone, based on scintigraphy and MRI imaging, reported Dyson.

Scintigraphy for Navicular Disease and Soft Tissue Injuries

Out of 264 horses with front foot pain, scintigraphic images of 36.6% of their limbs showed IRU on a bone scan in the navicular bone, Dyson noted. Scintigraphy and MRI grades were highly correlated.

"It was concluded that positive nuclear scintigraphic results are good predictors of injury or disease of the navicular bone; however, a negative scintigraphic result does not preclude significant disease of the navicular bone," she said. "It appears that if bone necrosis is the predominant pathological process, IRU may be normal. End-stage sclerosis (bone hardening) is also not associated with IRU."

The same 264 horses' scintigraphic images were also evaluated to see any IRU associated with soft tissue injuries. The most common soft tissue injuries with IRU were in the deep digital flexor tendon (13% of limbs) and in the insertion of that tendon on the coffin bone (14.3% of limbs).

"Positive nuclear scintigraphic results are good predictors of injury or disease of the deep digital flexor tendon and collateral ligaments of the distal interphalangeal joint (coffin joint), irrespective of the anatomical location of the lesion in the tendon or ligament," Dyson concluded. "But a negative scintigraphic result does not preclude significant injuries; however, in combination with MRI it can tell us something about the disease process. Nuclear scintigraphy was not useful for detecting lesions of the distal sesamoidean impar ligament. "

MRI Investigation In those 264 horses with foot pain, MRI showed that 82.6% of limbs had deep digital flexor tendon lesions, most often near the collateral sesamoidean ligament (59.4%) and navicular bone (59%). Many of these lesions were small and not clinically significant, she noted.

Lesions at the level of the first phalanx or long pastern bone (just below the fetlock) tended to be core lesions (90.3%), while the aforementioned lower lesions tended to be sagittal (front to back) splits and dorsal (upper surface) abrasions. Lesions of the deep digital flexor tendon and pathology in the navicular bone were associated.

Lesions of the distal sesamoidean impar ligament and collateral sesamoidean ligament were less common (38.2% and 10.5%), but both were also associated with navicular bone abnormalities.

"There are close interactions between injuries of the components of the podotrochlear apparatus, the deep digital flexor tendon, the navicular bursa, and the distal interphalangeal joint," Dyson concluded. "The navicular bone can't be considered in isolation. Core lesions of the deep digital flexor tendon at the level of the proximal phalanx may have a different etiology (cause) than lesions occurring further distally."

Cannon Bone Stress Fracture Dyson described a case of cannon bone stress fracture, which was a subtle fracture in the upper rear aspect of the bone in a forelimb (just below the back of the knee). The lameness worsened with more trotting and when the horse slowed down, which she noted is a hallmark of this injury. A few of these cases have pre-existing sclerotic changes, she noted.

The prognosis is generally a complete recovery with three months of stall rest and ascending walking exercise, she said.

Proximal Suspensory Desmitis A 4-year-old Warmblood was presented to Dyson because he'd lost quality of movement. "In

a young horse with loss of action, proximal suspensory desmitis is always in the forefront of my mind," she said.

In this horse, no abnormalities were detectable with ultrasound, scintigraphy, or radiographs. However, MRI located the suspensory lesion in the lateral lobe. "MRI has the potential to diagnose proximal suspensory desmitis in horses where we don't see any ultrasonographic abnormalities," she noted.

Coffin Joint Collateral Ligament Desmitis Dyson's last report described a study of coffin joint collateral ligament (CL) desmitis in which horses were divided into three groups:

Group 1 109 horses with primary CL injury.

Group 2 113 horses with CL injury along with other injuries.

Group 3 11 horses with primary CL injury, but no MRI examination.

Group 1 included 45 horses with lameness in one forelimb (unilateral), 59 with lameness in both forelimbs (bilateral), and five with hindlimb injury (one bilaterally).

Dyson reported that no localizing clinical signs were present in most horses, and pain was not apparent when palpating or manipulating the lower limb joints in any horse. However, lameness was considerably worse when the horses were worked in circles, especially on hard ground. She commented that horses with medial collateral ligament desmitis were sometimes more lame when the affected limb was to the outside of the circle. Abaxial sesamoid nerve blocks were the only ones that made all horses go sound.

The medial collateral ligament was injured in 73.4% of horses, and the lateral collateral ligament was also injured in 14.5% of horses. The remainder had injuries to only the lateral ligament. Horses that jump (including show jumpers and eventers) were overrepresented in the study, comprising 50 of the 109 horses.

Ultrasound found collateral ligament problems in only 44% of horses, and only six horses had abnormalities detectable with radiographs. But MRI found problems in all 109 horses.

Group 2 Eighty-five of the 113 horses (75.2%) had multiple concurrent injuries involving the coffin joint, deep digital flexor tendon, distal sesamoidean impar ligament, navicular bursa, or collateral sesamoidean ligament (often on the same side of the foot with collateral ligament injury). Medial injuries were more common, affecting 105 horses (93%). Ultrasound found collateral ligament abnormalities in only 13 horses (11.5%), and radiographs found no ligament problems, although they did find coffin bone fractures in three horses.

Group 3 All 11 of these horses had ultrasonographic abnormalities of the collateral ligament, and eight of nine evaluated with scintigraphy had positive findings.

Bony cystlike lesions at the attachments of the collateral ligament worsened the response to treatment in groups 1 and 3.

"Correlation between clinical findings and imaging modalities is enabling us to slowly unravel the complexity of the causes of foot pain and to begin to understand some of the risk factors for injury, different pathological mechanisms, and factors influencing prognosis," Dyson concluded. "It is important to emphasize that, although scintigraphy and MRI are hugely valuable tools, in a significant proportion of horses, a conclusive diagnosis can be reached with a thorough clinical examination, combined with radiography and ultrasonography. Clinical investigation should follow a logical, stepwise progression."

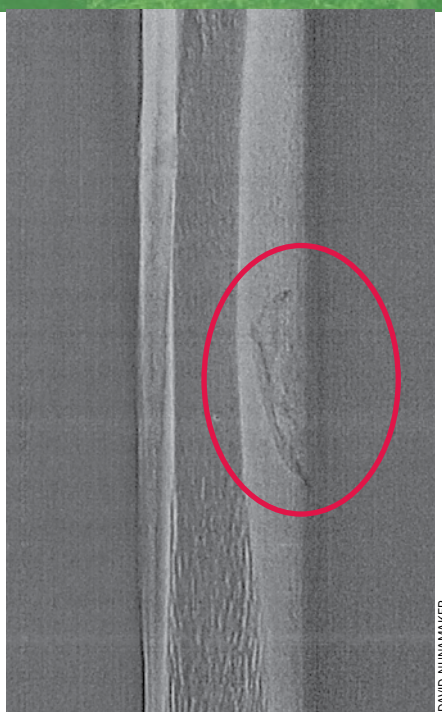
Allen added, "We (imaging referral practices) can't promise a full lameness work-up will be cheap, but we'll stay on it until we have a diagnosis. There's a real need for this in this country; too often a case doesn't get a good work-up and there's real value to doing this."

The State of Stem Cell Therapy

Stem cell therapy has received a good deal of attention in both human and veterinary medicine in recent years. It holds theoretical promise for treating conditions ranging from traumatic tendon and cartilage injury to liver failure, Parkinson's disease, and nerve/spinal cord damage, but it is still in its infancy.

Lisa Fortier, DVM, PhD, Dipl. ACVS, associate professor of clinical sciences at Cornell University, said, "Stem cells are not yet living up to the hype. We've got a long way to go before we really know what we're doing and can fine-tune these therapies."

Fortier and Roger Smith, MA, VetMB, DEO, MRCVS, PhD, Dipl. ECVS, professor of equine orthopaedics at the Royal Veterinary College in Herts, U.K., presented an in-depth session on the current state of stem cell research for horses. Their



DAVID NUNAMAKER

Horses with cannon bone stress fractures generally complete recovery with three months of stall rest and ascending walking exercise.

presentations described the specifics and challenges of stem cell work along with the evidence that supports its use for equine tendon and cartilage defects.

Stem Cell Background First, what is a stem cell? Even this seemingly basic answer is unclear, said Fortier. "The definition and identification of stem cells is constantly evolving," she noted. "There is no current consensus on a gold standard assay to isolate or identify stem cells."

Part of the challenge is that once stem cells differentiate into specific cell types (such as tendon or ligament cells), classifying them can be ambiguous. (Is that a stem cell, a tendon cell, or a stem cell that became a tendon cell?) Also, no single cell surface marker can differentiate stem cells from other cells. Instead, one must identify them by seeing what markers are present and absent, much like a combination lock (i.e., only a very specific combination of markers defines a stem cell).

Researchers are working to develop an assay combining many different markers to identify stem cells so they can determine absolute numbers of stem cells harvested and used in therapies. This will help clarify research on their use.

"To date, equine studies that have investigated the use of 'stem cells' contain no information regarding characterization of the cells before implantation or data concerning survival or function of the trans-

planted/grafted cells," noted Fortier.

While researchers aren't yet in agreement on the methods and criteria for identifying stem cells, some are working on more functional testing to find out what stem cells can do. To discuss this testing, we need to know a few additional "background basics" of stem cell therapy. These include whether they are embryonic stem cells (ES, cells derived from embryos or generated using genetic means) or adult-derived mesenchymal stem cells (MSC). The latter are further broken down into the type of tissue from which they were harvested—whether they came from bone marrow or fat (adipose) tissue (BM-MSCs and A-MSCs, respectively). Each type and location of stem cells carries specific nuances; they can't all be lumped together.

Embryonic stem cells carry a few challenges. Traditionally, there has been a lot of political/ethical debate about the generation and destruction of embryos to generate stem cells, and there has been a concern about immune rejection of the cells since they would contain the genetic material of an individual different from the recipient. Very current breakthroughs, however, suggest that embryonic stem cells can be made from adult somatic cells such as skin cells. This methodology involves the introduction of four genes that "re-program" a cell to become an embryonic stem cell. This methodology obviates the need for generation or destruction of embryos and it allows the establishment of patient-specific stem cells that would not be rejected by the immune system.

> **"Bone marrow-derived stem cells have received the most attention scientifically and hence are the best characterized"**
>
> DR. LISA FORTIER

Bone marrow-derived stem cells can be harvested from the sternum (breastbone) or iliac crest (part of the hip). These stem cells only comprise one in 10,000-100,000 of nucleated cells in bone marrow, said Fortier, but they "have received the most attention scientifically and hence are the best characterized." They are harvested with the horse standing and sedated, then they are cultured for about three weeks to increase their number to 10 million or so. They are then implanted into a lesion along with bone marrow supernatant (liquid), which contains growth factors to help heal the lesion. Since the cells come from the patient, there's no risk of rejection.

Adipose-derived stem cells have not done as well in some cell differentiation studies (which evaluate how well stem cells can be induced to grow into different tissue types, such as bone, muscle, or liver). Harvesting them results in more donor site morbidity (damage) than harvesting of BM-MSC. However, they do have their advantages; they don't have to be cultured for three weeks, so treatment of a lesion can occur quickly—within a couple of days. Fat tissue is harvested from the tailhead, then the fat cells are removed and what's left (about 50 million nucleated cells, about 2% of which are A-MSC) is injected into the lesion. This approach also carries no risk of rejection.

Several questions about stem cell therapy apply to all types of cells, said Fortier. They include the following:

- What's the best approach to using stem cells?
- How many stem cells do you need?
- Do we expect the stem cells to take environmental cues from surrounding tissues and just turn into what's needed, or do they need some guidance?
- How important are growth factors?
- What's the best way to grow stem cells in culture to gain maximum effect?

"There is a lot to learn, so we need to pick specific areas to focus on in order to optimize clinical implementation of stem cells," she commented. "The future of stem cell therapy is limitless for healing tendon, cartilage, laminitis, bones, nerves, etc."

Stem Cells for Tendon Lesions

"The horse is a professional athlete, and tendon injuries are extremely common," noted Smith; one study found that they affect 23% of National Hunt horses in training and 46% of limb injuries at racecourses.

He focused on the superficial digital flexor tendon (SDFT) in particular, noting that a large part of its function is to store energy via its elasticity and return that energy to the horse for the next stride. "That's what makes the horse an efficient runner," he explained. "The horse is estimated to be 120% energy efficient at the gallop." The downside, of course, is injury when the tendons and ligaments are overstretched.

When a tendon is injured and subsequently healed, the scarred tendon is less elastic than normal tissue, putting it at risk of reinjury; one study of National Hunt horses found that 56% of those with SDFT injury suffered reinjury. "This is the rationale behind use of stem cells to treat tendon overstrain injuries—we need regeneration (of normal tissue) rather than repair (scarred tissue)," Smith explained.

Equine MSC cultured in the laboratory create a matrix of tendon tissue that is "remarkably ordered," he observed. This is one of the keys to healing tendons—the cells must be organized linearly so they can handle the linear stress placed on them, rather than being disorganized so they can't stretch effectively.

One good thing about tendon lesions is that they generally form a closed cavity within the tendon, which helps hold stem cells in place and provides a vascularized scaffold (granulation tissue bed with blood vessels) to help organize healed tissue and provide blood supply, growth factors in the fluids present to help heal the lesion, and a mechanically appropriate environment.

Smith reported that lab animal studies have found that treatment of surgically created tendon and ligament lesions with MSCs results in better tissue organization, composition, and mechanics compared to controls. In addition, an equine study in the U.K. using BM-MSCs found that in 82 of 168 treated racehorses that were available for follow-up after one year, there was a 78% success rate (no re-injury) compared to 43% of horses conservatively treated in another study—a 35% improvement in success rate. More specifically, the success rate in National Hunt horses (in training and racing) was 82% of 71 horses, and the success rate in 11 flat racing horses was 50%. Twenty-four sport horses in other disciplines had an 87% success rate, compared to a 57-77% success rate with conservative treatment in another study.

He noted that horses that re-injured had a significantly longer interval between injury and treatment (83 vs. 44 days), suggesting that delayed treatment resulted in more fibrosis of the lesion. He now recommends earlier harvesting of bone marrow (within one month of injury) and treatment. Pre-injury harvesting and storage of cells may also prove beneficial, as might storage of stem cells recovered from that horse's umbilical cord at birth.

> **"Stem cells won't remove fibrous tissue once it's there, so treatment will be less effective on chronic cases."**
>
> DR. ROGER SMITH

"Stem cells won't remove fibrous tissue once it's there, so treatment will be less effective on chronic cases," he advised. "I recommend it for first-time injury, but sometimes it's also been tried on horses with more chronic presentation or those that have had poor success with other treatments."

Less evidence is available regarding the value of A-MSCs in tendon injuries; Smith reported that a pilot study using the collagenase model of tendon injury found improved tissue organization and increased specific gene expression compared to controls. Although this approach has been used in many U.S. horses, clinical results have yet to be published.

Both treatments are followed by a 48-week protocol of rest and controlled exercise designed to provide appropriate mechanical stimulus to the healing cells without causing further damage. The protocol is adapted based on the individual horse's progress.

"There are some encouraging aspects to this technology, although definitive proof of efficacy is still lacking," Smith noted. "Furthermore, there have been no direct comparisons between the two techniques (BM-MSC and A-MSC). Combining stem cell therapies with other more established methods to prevent re-injury, such as desmotomy of the accessory ligament of the superficial digital flexor tendon (superior check ligament desmotomy), makes a lot of sense and might have value. But it must be remembered that there are still considerable gaps in our knowledge, although the technology is developing rapidly."

He explained the harvesting and treatment procedures in detail for the audience.

Stem Cells for Cartilage Lesions One advantage of using stem cells to treat cartilage lesions is that the cells are harvested and inserted during a single arthroscopic surgery; no laboratory culture time is required. The technique involves removing any calcified cartilage, using a micropick to perforate cartilage and thus get growth factors from the bone beneath, and filling the defect with a stem cell mixture harvested from bone marrow. The mix includes thrombin to break fibrinogen down into a fibrin scaffold, which holds the stem cells and growth factors in place.

"First you dry the area with helium, then put in tricalcium phosphate (if there is a bone void underneath the cartilage), then put in the graft (stem cell mixture)," Fortier explained. "It clots immediately and sets in 30-45 seconds, and you can sculpt it so it fits in perfectly."

She discussed one ongoing study, funded by the Grayson Jockey-Club Research Foundation, of young (2- to 5-year-old) horses using this technique and BM-MSC in 15-mm full-thickness surgically created defects.

Eight months post-surgery, treated sites had significantly more fill of the lesions (more than 75% fill vs. less than 25% fill in control sites on the same horse) and improved texture of the repair. Glycosaminoglycan (GAG) content (which helps hydrate and lubricate the joint) was not normal in treated lesions, but it was better than in control sites.

"Stem cell therapy is an exciting technology, but it's still developing," summarized Smith. "We must have sensible expectations for the therapy; this field is high on emotion and low on science. We're trying to readjust that balance, but certainly for your clients they'll always be attracted to stem cells and you have to temper that enthusiasm with explanation of where the technology currently is."