Advancements in diagnostic methods for identifying the cause of pain in the horse

Christopher E. Kawcak, DVM, PhD, Diplomate ACVS & ACVSMR
Equine Orthopaedic Research Center, Colorado State University

The purpose of this discussion is to provide evidence of how current imaging techniques have improved early diagnosis of musculoskeletal diseases, demonstrate correlation of imaging results to pathologic changes in tissues, and to describe current research efforts to improve diagnosis.

Imaging results are difficult to use effectively for predicting and characterizing musculoskeletal injuries, and especially difficult to use if the goal is to identify parameters indicative of prognosis. The limitations are due to several factors, such as the limited ability to discern normal tissue adaptation from early disease, the limited use of front line volumetric imaging techniques (usually due to cost), lack of prospective data on imaging biomarkers in relation to disease presence and outcome in the horse, modest correlation between pain and imaging results, and limited follow-up imaging. There are a few experimental studies in which imaging biomarkers have been assessed in models of joint disease, but long-term clinical studies are lacking in veterinary medicine.

Radiography

Results of radiographs have been scrutinized because of the significant amount of disease needed to impart changes on the images. However, in recent years, digital technology has allowed clinicians to manipulate images in order to improve lesion detection. Yet despite these improvements, a 30-40% change in bone mineral density is still needed to detect a lesion radiographically, allowing for significant tissue changes to occur prior to detection. Diseases such as osteoarthritis are also slow to develop, making radiographic changes as markers of disease difficult to use in a timely fashion – such as for medication efficacy studies. In addition, it appears from recent research that subchondral bone from OA joints changes in opposing fashion – ie, the bone increases in mass but decreases in quality and density. Therefore, even with significant reduction in bone density, as occurs with OA, the resulting increase in bone tissue mass clouds the clinician's ability to detect subtle bone changes. Joint space width has been used for decades as a measure of joint disease severity, yet it lacks predictive validity for clinical outcomes in humans. The use of joint space width as a biomarker in horses is subjective in horses and it is usually only mentioned in cases of severe disease.

We continue to include radiographic assessment of joint disease in our studies and continue to find that when compared to treadmill-exercised horses, those with osteochondral fragments have significant worsening of radiographic lysis, proliferation and osteophyte formation at the fragment site at the end of the studies. The development and use of volumetric imaging techniques, such as MRI and CT have helped clinicians better interpret and validate the significance of findings that were once assumed to be pathologic. MRI is also being extensively explored as an imaging modality that can be used in the FDA approval process of new medications in humans.

Ultrasound

Ultrasound has been the gold standard for diagnostic imaging of soft tissues such as tendons and ligaments. It has been used routinely in equine practice since the early 1980's and today remains a critical part of any equine practice. Morphologic changes in tendons are characterized using ultrasound, and physiologic changes, although not directly described using ultrasound, can be assumed from the findings. Structural changes such as cross sectional area of tendon, cross sectional area of lesion, volumetric size of a lesion, echogenicity and fiber alignment have all been described and routinely used to characterize severity of a lesion. However, a readily accessible site must be present in order to visualize the lesion. In the SDFT, that is usually not a problem. However, in the DDFT in the hoof, only limited access can be gained and the lesion may lie outside that window of visualization.

Functional measures using ultrasound have been developed and studied in horses. Ultrasound elastography is the measure of tissue displacement when compression is applied to a tissue as a measure of mechanical properties. Strain ultrasound elastography, or sonoelastography, has been used in horses in preliminary studies. Stress can be applied several ways, but the application by manual force from the probe is most common. Strain maps are displayed that can be evaluated subjectively, or referenced to a known tissue such as fat for a semi-objective measure. Elastography has been used on cadaver limbs and found to be consistent in it measure of tendon strain. Other ultrasound techniques that may have some value as biomarkers of tendon disease include Doppler Ultrasonography and speed of sound measurements.

Nuclear Scintigraphy

In a study in which we evaluated the effects of 6 months of treadmill exercise on 2-year-old horses, uptake of radiopharmaceutical was significantly higher in the metacarpophalangeal (MCP) and carpal joints of those that were exercised compared to age-matched non-exercised horses. The severity of uptake correlated with the degree of gross articular cartilage lesions in the MCP joint, but the significance of those lesions on future soundness were unknown. It was concluded from this study that exercise alone can induce a significant scintigraphic response. In a separate study though, nuclear scintigraphy was able to be used to separate those horses with osteochondral fragments from those that were only exercised. Although nuclear scintigraphy appears helpful in early diagnosis of disease, it lacks the specificity of being able to detect the exact lesion in the joint. However, it may be a useful screening and monitoring tool for OA.

Computed Tomography

Computed tomography has been used clinically to detect occult lesions in subchondral bone of joints and has played a limited role in presurgical planning. Detection of subchondral bone density by CT has been performed, and in our laboratory, we have detected Computed Tomographic Osteoabsorptiometry (CTO) patterns of density that appear to be common in cases of joint disease. For instance, in postmortem samples from racehorses, it is not uncommon to see vertical demineralization patterns in the distal third metacarpal condyles in the area where condylar fractures commonly occur. The limitation of clinical CT is that some consider the resolution to be too great in most instances to detect subtle changes in subchondral bone. We have seen something similar in that the bone formation response to disease and exercise in the subchondral bone plate is below the resolution of the typical clinical CT scanner. However, in the trabecular bone, the response seems great enough in most instances to detect a difference. Therefore, it appears that CTO density pattern can be useful for characterizing insidious disease processes, such as palmar arthrosis, which can lead to OA. Furthermore, the images, once acquired, can be cut into any plane and analyzed. We have found this useful as linear, saggitally oriented demineralization patterns have been seen in the palmar aspect of MCIIIs, which appear to occur in areas predisposed to condylar fractures.

Computed tomographic imaging is usually only associated with imaging of bone structures. However, recent advances in contrast-enhanced computed tomographic imaging has improved its use for characterizing soft tissue diseases, especially in the hoof. Studies have shown that in some cases intra-arterial application of contrast is as good if not better than standing MRI for visualizing certain structures within the hoof. Intra-articular application of contrast has also been used and provides critical information concerning soft tissues of joints, especially those joints, such as the stifle, that can rarely be imaged using MRI. Dual energy computed tomography has also been studied and appears to have value in characterization of soft tissues and detection of bone marrow edema.

Magnetic Resonance Imaging

Magnetic resonance imaging has revolutionized the detection of subtle joint diseases in all species, and in particular, the detection of soft tissue and articular cartilage lesions. However, as Ekstein pointed out, its resolution is limited and subtle bone and joint lesions can sometimes be missed. Besides this though, the fact that various sequences can be used to highlight various tissue characteristics, and the addition of contrast agents that can be correlated to various biochemical reactions in tissues, MRI has the greatest ability to be used as a predictive marker of disease. A recent review has shown that measures of quantitative cartilage morphology, cartilage defect and bone marrow lesions, bone shape and attrition and subchondral bone area were the most promising as imaging biomarkers.

Magnetic Resonance Imaging has been the gold standard for characterizing soft tissue lesions in human orthopedics for decades. Recently, MRI has become routine for characterizing certain types of tendon lesions in horses, particularly in the hoof. Tendon is mostly characterized as having low signal on T1 and T2 images, displaying a black image, but displays an increased signal with disease. However, cartilage metaplasia in high-load areas, and the “Magic Angle Effect” in which tendon fibers are oriented greater than 55 degrees to the magnetic field can increase the signal of the tendon. Therefore, great care is needed in evaluating these images. The greatest asset of MRI is the ability to characterize a tendon in 3 dimensions regardless of its location. Structural and physiologic changes can be characterized, and have been correlated to histologic changes. Although MRI has gained popularity in assessing tendon damage in hooves, it has not been used to characterize other tendons. It's impractical to use for SDFT lesions, and provides little additional information than ultrasound. In theory it may be useful for detecting early, subtle lesions, but again suffers from high costs and impracticality for use on a preventative basis.

Summary

It appears that imaging will always remain a key component of orthopedic disease diagnosis, but at this time we need to continue pursuing greater sensitivity in its ability to be used to detect subtle joint damage and to predict those individuals that are predisposed to OA.