MRI, CT provide early link to diagnosing injuries, disease in horses

Selecting the proper modality will help equine practitioners identify medical problems that were previously difficult to pinpoint

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Magnetic resonance imaging (MRI) and computed tomography (CT) have provided practitioners with new avenues to better diagnose a variety of disease conditions in horses before the disease process takes hold and causes life-threatening complications.

MRI is available at Washington State University. This exciting advancement in cross-sectional imaging provides an important diagnostic tool in many equine injuries and offers several advantages over other imaging technologies. In particular, MRI yields images with unparalleled tissue contrast and anatomic definition.

Furthermore, the ability of MRI to demonstrate physiologic as well as anatomic information is a tremendous benefit in the early detection of many equine conditions. MRI also excels in the evaluation of the brain and skull for neurologic conditions. Consequently, the use of MRI in equine patients provides for more timely intervention; therefore improving the prognosis and long-term outcome.

Imaging equine patients

With MRI imaging, the anatomic region of interest...
est must be positioned within the center of a strong external magnetic field generated by the MRI system.

Currently, horses are imaged with MRI systems designed for imaging human patients and only those parts of the horses which can be positioned within the magnet bore are able to be examined. Consequently, most MRI systems are able to image adult horse legs from the level of the carpus or tarsus to the distal foot and from tip of the nose to the first or second cervical vertebrae. When imaging the legs of a horse, the anesthetized horse is positioned next to the MRI gantry and either forelimbs or hind limbs are extended into the center of the magnetic field. For imaging the head and the proximal cervical vertebrae of a horse, the head and neck are extended into the bore of the magnet as far as possible (Images 1A, 1B, p. 43).

Young foals and small ponies, which are small enough to fit within the MRI gantry, may have their entire body imaged. Newer “open-magnet” design MRI systems should facilitate imaging of the proximal limbs and entire cervical region. In the future, MRI systems will be designed to facilitate imaging of a standing horse.

**Technology**

MRI is accomplished by using the magnetic properties of tissues and does not rely upon radiation exposure.

The actual physics of MRI are complex, however a brief and simplified summary is helpful.

When the area to be imaged is placed within the bore of the magnet, it is under the influence of a strong magnetic field. Most tissues have magnetic characteristics which interact with the magnetic field created by the MRI system. Free protons (hydrogen protons) within tissues, acting as small spinning magnetic dipoles, are subjected to repetitive perturbing radiofrequency pulses specifically tuned to the resonance frequency of the spinning dipoles. Under the influence of these perturbing pulses, the protons are displaced from their original alignment. Once the perturbing pulse is discontinued, the spinning protons return to alignment relative to the external magnetic field. As the protons realign they emit a radiofrequency signal that is collected to create the image.

The signal strength and characteristic emitted by each individual tissue is dependent on the individual magnetic behavior of the spinning protons and its immediate environment. For most applications, a receiving coil is placed closely around the anatomic region of interest to collect the emitted signals (Image 2).

**Diagnostic comparisons**

One advantage of MRI is the fact that it displays excellent anatomic and physiologic detail in both the osseous and soft tissue structures.

This is a distinct advantage over ultrasound which is effective for examining soft tissues but is limited in evaluation of osseous structures, and over radiography and computed tomography (CT) which are excellent for evaluating osseous structures but suffer in evaluation of the soft tissues. Similar to ultrasonography and CT, MRI yields images as tomographic sections or slices. The MRI operator determines the thickness and orientation of the slices. MRI of equine cases is commonly acquired in two to three orthogonal image planes. Additional image planes can be selected to better evaluate specific structures or precisely define anatomy. Similar to other digital imaging modalities, it is possible to reconstruct alternative MRI planes in 2- and 3-D images.

**Imaging capabilities**

MRI imaging is routinely performed using a variety of several possible acquisition sequences and the region of interest is examined with multiple sequences. Each sequence displays different anatomic, physiologic and pathologic information. Therefore, sequences of the same tomographic slice can appear quite different.

A common MRI protocol, known as spin-echo imaging, includes three types of acquisition sequences: T1-weighted (T1-wt), proton density (PD), and T2-weighted (T2-wt) images. All or some combination of sequences is acquired in each anatomic plane (Image 3).
The T1-wt images highlight the structural characteristics of tissues and are particularly useful in evaluating the anatomy of bone and some soft tissues. T1-wt sequences are also used for the visualization of MRI paramagnetic contrast agents. Proton density images offer excellent tissue contrast and are used for evaluating both osseous and soft tissue structures. T2-wt images emphasize the fluid characteristics of tissues and are sensitive for detecting synovial effusions, cystic lesions and areas of inflammation or edema.

**Other useful sequences**

In addition to spin-echo protocols, several other imaging sequences can be useful.

For example, sequences that suppress the normal fat signal may allow for recognition of edema and inflammation which are masked by the normal high signal of fat. Fat-suppression images are particularly useful for identification of trabecular bone edema and inflammation associated with the early phases of disease (Image 4).

Other protocols, such as gradient echo imaging, are useful when very thin tomographic slices are desired. Gradient echo imaging makes it possible to obtain contiguous or overlapping slices as thin as 1-2 mm. Furthermore, 3-D volume acquisitions are useful when complex and multiplanar reconstructions are desired. Other sequences, like magnetic transfer contrast imaging, can enhance contrast between adjacent tissues such as the articular cartilage and synovial fluid within joints. New sequences are currently under development and will also lead to useful protocols for future equine patients.

**Orthopedic problems**

MRI can provide the diagnosis in equine orthopedic cases when other modalities failed to clearly identify the cause of lameness. This is especially true for soft tissue injuries around joints and in areas difficult to image by other methods. Many important structures, such as the suspensory ligaments, inferior check ligaments, distal sesamoidean ligaments and flexor tendons, are challenging to evaluate in their entirety from origin to insertion. With MRI, it is possible to detect lesions within the ligaments and tendons along their entire course (Image 5).

**Osseous injuries**

Several osseous injuries can be diagnosed with MRI prior to detection by other modalities.

In particular, injuries, which induce abnormal subchondral and intramedullary stress, early in the disease process, can be readily demonstrated. Bone edema and inflammation result in a focal increase in the fluid content. Using fluid-sensitive MRI sequences, it is possible to illustrate these changes far in advance of radiographic detection. The early recognition of such lesions may offer the opportunity to intervene and improve outcome. This is especially crucial in articular injuries when early diagnosis and intervention may prevent continued cartilage destruction and minimize the degenerative progression.

Importantly, MRI has provided an imaging technique to allow recognition of initial onset of navicular degeneration prior to detectable radiographic alterations. Early in the disease process, MRI will demonstrate inflammation of the synovial invaginations and within the medullary cavity of the navicular bone.

In addition, the associated soft tissue structures such as the suspensory ligaments of the navicular, the navicular bursa and the impar ligament can be critically evaluated using MRI (Image 6).

**Limiting factors**

There are several important limitations to consider with MRI in equine patients.

The cost of an MRI examination may be prohibitive for many horse owners and the potential value of a MRI exam must be weighed against the diagnostic sensitivity of less expensive imaging modalities.

In certain equine conditions, MRI may provide the earliest diagnosis and may be the most cost-effective imaging technique available. Additionally, MRI systems capable of imaging live horses are available at only a few veterinary institutions worldwide. With current MRI technology, the requirement of general anesthesia and the time required for scanning must be an ac-
ceptable risk for each patient. Routine MRI examinations require between 30 and 90 minutes depending upon how many areas are examined and how many sequences are required for each area. Future development of specialized MRI systems capable of imaging a standing horse would avoid the requirement for general anesthesia and will rapidly expand equine applications and acceptance.

Computed tomography

CT is a radiographic imaging modality that excludes unwanted planes or sections of anatomic detail by virtue of motion. The desired plane of image is reconstructed using complex mathematical processing using the computer’s programs for acquisition of data and the subsequent processing. Axial (transverse) sectional images of the body or area of interest are obtained by rotating an x-ray tube around the subject. Opposing the x-ray tube are sensitive detectors that record the amount of x-ray that penetrates the subject at multiple points through a 180-degree arc. The emergent radiation intensity is recorded and a digital record is made. The digital record is translated and restored on a cathode ray tube (CRT) as an array of bright dots on a black background. Increasing brightness of the pixel represents reduction of transmitted radiation and areas attenuating radiation are seen as white and gray; those allowing passage of radiation are darker gray or black. The images are recreated to be equivalent to conventional radiography.

Post acquisition processing allows the operator to investigate windows of radiographic detail and compare x-ray transmission or attenuation using Hounsfield numbers, which provide a standard scale of tissue attenuation compared to air, water and heavy metal. Zero represents the attenuation produced in pure water. Negative numbers, less than zero, represent material or tissue that is less attenuating than water (e.g., fat, air) and positive numbers, greater than zero indicate materials or tissues with greater x-ray attenuation than water (e.g., soft tissues, mineral, bone, metal). Conventional radiography uses a single projection, and an image is recorded in film emulsion according to the relative attenuation of the x-ray beam. Discrimination of densities requires 5 percent difference in attenuation. CT uses numerous projections of the same anatomy, and the discriminated contrast may be 1 percent or less.

The transmitted radiation intensity is recorded as a digital function representing small cubes (voxels), which when viewed perpendicular to the beam direction the voxels are stacked in respective location on an “X” and “Y” axis, which forms a cross-sectional image. Perhaps the image is best compared to a crossword puzzle, which is a “cross-image puzzle”, which represents a thin slice of the patient. A series of these slices (puzzles) are stacked and contain mutual information that can be accessed in the third dimension or the “Z” axis of the puzzle. Reconstructing the “Z” axis or

Image 7: Transverse images of the skull of a horse were made to study the congenital malformation or dental tumor occurring in a premolar in the left mandible.
third dimension of the image is a simple task for the computer. Images created by CT are the product of diagnostic x-ray radiation and require similar skills and fundamentals for interpretation as conventional radiography. Cross-sectional anatomy, sagittal and parasagittal anatomy, and anatomy in sectional dorsal planes are the challenges to accurate interpretation. Advantages are found in the improved detail and increased information that is acquired when using digital acquisition of images. Locations that provide CT services may have adequate expertise to assist with interpretation of the images. One might also solicit the assistance of a veterinary radiologist, many of whom are qualified to interpret CT images.

**Large animal medicine**

Computed tomography is routinely used for examining small animals and it is often used for the examination of larger patients. Perhaps the best application of CT imaging is for imaging the skull and teeth of horses (Image 7, p. 47). CT is also valuable for imaging soft tissues especially in the region of the pharynx and skull. Arthrography is often an area of application of CT (Image 8) and it is especially helpful to apply the image reconstruction programs to visualize all three planes and the three dimensional surface characteristics. Contrast is often used in conjunction with CT and as with conventional radiography tissues are enhanced and shorter scales of contrast are produced.

Computed tomography is an imaging modality that will remain a sophisticated imaging modality of great value in veterinary medicine. Each imaging modality may provide superior conspicuity for selected examination purposes. MRI, CT, diagnostic ultrasound and conventional radiography are not mutually exclusive and should be selected according to respective advantages, purpose and cost.

**Suggested reading**