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Magnetic Resonance Imaging of the Equine Patient: A Comparison of High- and Low-Field Systems

Natasha M. Werpy, DVM, Dipl ACVR

As use of magnetic resonance (MR) imaging evolves in veterinary medicine, the importance of field strength will be a continued source of debate. This article addresses the fundamental differences between high- and low-field MR imaging systems. The magnet and room construction, examination time, image quality, and implications on diagnostic accuracy are discussed. Although many injuries can be well characterized with both high- and low-field systems, a high-field system is required to identify certain lesions. Further studies are needed to define the difference in the detectability of lesions on high-field versus low-field MR imaging systems.
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Magnetic resonance (MR) imaging is becoming the gold standard for diagnosis of musculoskeletal injury in veterinary medicine, as it has been in human medicine for at least a decade. MR imaging provides excellent visualization of soft tissue and osseous injuries. Several MR systems, both high- and low-field, are available for imaging equine patients. High-field systems designed for use in human medicine have been modified to allow imaging of equine patients. Currently, there are two low-field MR systems specifically designed for equine patients. This article addresses the fundamental differences between high- and low-field MR imaging systems. The magnet and room construction, examination time, image quality, and the implications on diagnostic accuracy are discussed, with reference to the current literature and personal experience.

Low- versus High-Field MR Systems

High-Field Systems

High-field MR imaging systems are defined as having a field strength of 1.0 tesla or greater. One tesla (T) is approximately 20,000 times the earth's magnetic field.[1] Creating a high-field strength MR system requires a superconducting magnet. Superconductivity is a characteristic of certain metals that have no resistance to electrical current when cooled to an extremely low temperature. A high-field MR system requires a cryogen, such as liquid helium, to maintain this extremely low temperature. The cryogen circulates throughout the MR system, eliminating electrical resistance in the circuit. Allowing current to flow through the circuit without electrical resistance creates an environment capable of producing field strengths of 1.0 T and higher. Many research centers use high-field, small-bore magnets ranging from 7.0 to 12 T for imaging tissue samples. These systems can characterize the articular cartilage layers and provide extremely detailed imaging of tissue samples. Clinical imaging systems with a field strength of 3.0 T have been introduced into the human market relatively recently; however, 1.5 T is still considered the gold standard. The high-field MR systems currently in use in veterinary medicine are human systems that have been modified to allow imaging of equine patients. High-field, small-bore systems allow extremity imaging from the carpus and tarsus distally (Fig. 1). High-field, large-bore magnets are available that allow imaging of the head and cranial cervical spine in addition to the extremities (Fig. 2).

Low-Field Systems

Low-field MR systems are defined as having a field strength of up to 0.3 T.[2] Both of the currently available equine-specific MR imaging systems utilize low-field permanent magnets. Hallmarq Veterinary Imaging, Ltd. (Guilford, UK) has a 0.26 T system that can image both standing and anesthetized patients (Fig. 3). Universal Medical Systems, Inc. (Solon, OH) has two MR systems available. The Vet MR has a field strength of 0.2 T and can be used for extremity imaging. The Vet MR Grande has a larger aperture with a field strength of 0.25 T, allowing imaging of the head and cranial cervical spine in addition to the extremities (Fig. 4). Permanent magnets create a magnetic field using the ferromagnetic properties of

Clinical Sciences, Orthopaedic Research Center, Colorado State University, Fort Collins, CO.
Address reprint requests to: Natasha M. Werpy, Clinical Sciences, Orthopaedic Research Center, Colorado State University, 300 West Drake Road, Fort Collins, CO 80523-1678. E-mail: nmwerpy@colostate.edu

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Figure 1 A sagittal proton density image of a foot produced by a 1.0 T OrthOne from ONI Medical Systems. The navicular bone has an erosion in the flexor surface and the endosteal margin is irregular. At the level of the erosion in the navicular bone, the deep digital flexor tendon is focally enlarged. There is intermediate and low signal intensity tissue that extends from the erosion in the navicular bone to the dorsal margin of the deep digital flexor tendon indicating adhesions.

certain metal alloys.[1] The magnetic field is induced into the materials at the time of manufacturing. Therefore, current is not required to create the magnetic field.

Financial Implications

The purchase price of high-field systems is substantially higher than that for a low-field system, utilizing a permanent magnet. There is a small degree of overlap in purchase price between low-field systems and high-field small-bore systems. The industry standard for annual service contracts is approximately 10% of the purchase price. The cryogens required to maintain the magnetic field in a superconducting magnet are expensive, thus the annual maintenance costs for a permanent magnet are usually less than for a superconducting magnet.

Room Construction and Equipment

Room Construction

Construction requirements for both high- and low-field MR systems are predominantly determined by two factors.[1] Individuals must be protected from the potentially hazardous effects of interaction with the magnetic field. Ferrous metal objects may become dangerous projectiles, pulled into the magnet at great speed. Severe injury and death have resulted from oxygen tanks or other ferrous objects being accidentally allowed into MR suites. Patients with pacemakers or ferrous metal implants must be protected from the detrimental effects of the magnetic field. The area of the room affected by the magnetic field can be decreased by shielding placed inside the magnet housing. This decreases both the area under the influence of the magnetic field and the risk to patients and personnel. The MR system must also be shielded from outside radiofrequency (RF) signal. External RF signals, such as

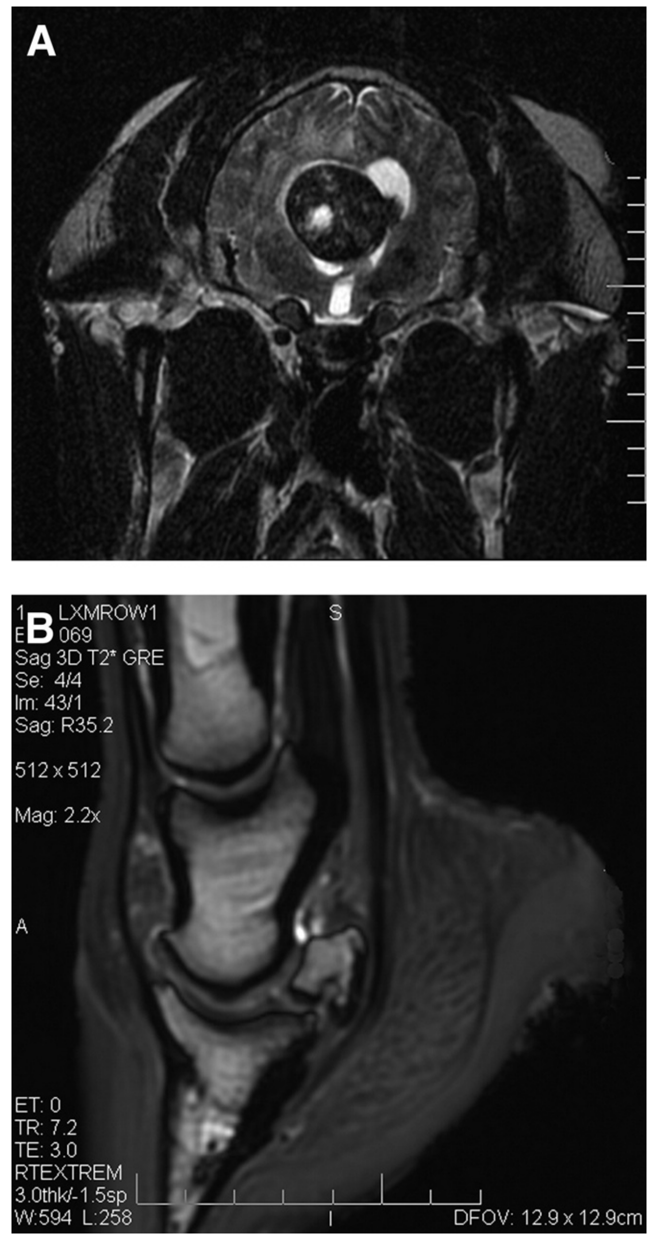

Figure 2 (A) Transverse fast spin echo image T2-weighted image of a head obtained using a 1.5 T GE Signa Echospeed magnet. There is a large space occupying mass of heterogeneous low signal intensity within the brain, surrounded by hyperintense signal. The horse showed depression and occasional head-pressing behavior. Post mortem examination demonstrated the presence of a cholesterol granuloma. (B) Sagittal T1-weighted spoiled gradient echo image of a foot obtained using a 1.5 T GE Signa Echospeed magnet. There is a small focal defect in the flexor cortex of the navicular bone at the junction of the proximal two-thirds and distal one-third, characterized by increased signal intensity. This early lesion was only seen in 2 contiguous images obtained with a slice thickness of 1.5 mm. There is mild endosteal irregularity of the palmar cortex of the navicular bone and a large distal border synovial invagination. Lameness was sudden in onset and of 6 weeks' duration.