Lesion detection of osteochondral defects is different when evaluating high field versus low field magnetic resonance systems. Motion-simulating studies performed in standing sedated horses further exacerbate these differences. Articular cartilage defects were not detected on the low field images. General anesthesia in upper limb studies should be performed on low field systems to prevent motion artifact that can obscure lesions. Authors’ address: Gail Holmes Orthopaedic Research Center, Colorado State University, 2503 Bay Farm Road, Fort Collins, CO 80523; e-mail: nmwerpy@colostate.edu. © 2008 AAEP.

1. Introduction

Does the improved image quality achieved with high field systems translate into increased diagnostic accuracy? Papers have concluded that there is no statistically significant difference between the diagnostic accuracy of low field and high field magnetic resonance (MR) systems. Critical analysis of the papers comparing high and low field MR images revealed that the lesion type, size, and severity are neither specifically selected for nor discussed. In reality, these are the most important intrinsic factors determining the appearance of lesions. A currently available low field system can image standing and anesthetized patients. The motion in the standing sedated horse can be frequently identified on images of the fetlock joint and more proximal aspects of the limb. Motion on these studies impacts the image quality and may prevent identification of small but clinically significant lesions. Minimal differences have been observed when comparing standing and anesthetized low field images of feet. The distal surface of the metacarpus and metatarsus in the fetlock joint is the most difficult to image with MR because of the curved distal margin and thin articular cartilage. This joint tests the limits of MR systems and the capability to resolve fine detail. We present the preliminary results of an ongoing study evaluating detection of subchondral bone and articular cartilage defects in the fetlock joint. The purpose of this study was to evaluate the effect of field strength on MR images of fetlock joints with subchondral bone and articular cartilage defects. The images were taken at three field strengths (0.27, 1.0, and 1.5 T)
and the potential effect of motion on 0.27-T images was assessed.

2. Materials and Methods
Four cadaver limbs were obtained, and the sesamoid bones and palmar soft tissues were removed from the fetlock joint. Four different lesions were created on each limb. The lesions were curetted to specific dimensions. The lesions consisted of the following (length × width × depth): a 10-mm in-length linear fissure in the articular cartilage that extended to the subchondral bone, a 5 × 10 × 2-mm defect including the subchondral bone, a 5 × 5 × 2-mm defect into the subchondral bone, and a 5 × 5-mm full thickness articular cartilage defect to the level of the subchondral bone. In two limbs, the lesions were created proximal to the first phalanx on the palmar aspect of the third metacarpus. In two limbs, the lesions were created on the distal aspect of the third metacarpus palmar to the transverse ridge. The lesions were created at two different sites to assess if there is a difference in lesion detection between a lesion bordered by fluid only and a lesion bordered by fluid and an opposing articular surface. The fetlock joints were placed in saline and imaged with two high field systems (1.5 and 1.0 T) and one low field (0.27 T) system. Sagittal and oblique frontal images with the angle perpendicular to the lesions were performed on all limbs. The following sequences were performed using all three systems: proton density (PD), T1 weighted gradient echo (GRE), T2* GRE, PD T2 weighted fast spin echo (FSE), and short T1 weighted inversion recovery (STIR). In addition to the previously listed sequences, motion-corrected T1 GRE sagittal low field images were made with and without simulated motion. PD fat saturation (FS) images were acquired with the high field systems, because this sequence is not available on the low field system. Sequences used were individually maximized for clinical imaging and were not altered.

The motion in the low field images was intended to represent the swaying that occurs in the standing sedated horse. The specimens were moved back and forth; the total vertical distance, which ran in the dorsal to palmar direction to the limb, was 10 mm. The limbs were moved three times in a 10-s interval. Next, they were not moved for 10 s, and then, they were moved again three times in a 10-s interval. This process was continued until the sequence completed acquisition. The motion-correction software can detect what is considered unacceptable motion for clinical imaging. The motion did not exceed the acceptable amount, as determined by the software program, to create a diagnostic study. The motion created for this study was far less than what is commonly encountered in a standing and sedated horse.

The images were reviewed by two board certified radiologists (NW and AP). The condyles of the third metacarpus were divided into medial and lateral halves, and each of these regions was evaluated. The presence or absence of a lesion was determined. If a lesion was determined to be present, it was measured and assigned a confidence score from 0% to 100%. The sequence that the reader determined best showed the lesion was recorded and used to measure the lesion.

3. Results
The fissure in the articular cartilage that extended to the subchondral bone was not identified on any of the studies.

The results for the subchondral bone defects with the dimensions 5 × 10 × 2 mm were as follows: four of four were detected on images produced at 1.5 T with an average confidence score of 100%, four of four were detected on images produced at 1.0 T with an average confidence score of 100%, two of four were detected on images produced at 0.27 T (standard images) with an average confidence score of 100%, two of four were detected on images produced at 0.27 T (motion-corrected sequences) with an average confidence score of 50%, and one of four was detected on images produced at 0.27 T (motion-corrected sequences) with an average confidence score of 40%. Of the two lesions not detected on the 0.27-T standard images, one was located on the distal aspect of the condyle, and one was located on the palmar aspect of the condyle. Of the three lesions not detected on the 0.27-T motion-correction images, one was located on the distal aspect of the condyle, and two were located on the palmar aspect of the condyle.

The results for the subchondral bone defects with the dimensions 5 × 5 × 2 mm were as follows: four of four were detected on images produced at 1.5 T with an average confidence score of 100%, four of four were detected on images produced at 1.0 T with an average confidence score of 90%, two of four were detected on images produced at 0.27 T with an average confidence score of 40%, and one of four was detected on images produced at 0.27 T with an average confidence score of 40%. Of the two lesions not detected on the 0.27-T standard images, one was located on the distal aspect of the condyle, and one was located on the palmar aspect of the condyle. Of the three lesions not detected on the 0.27-T motion-correction images, one was located on the distal aspect of the condyle, and two were located on the palmar aspect of the condyle.

The results for the full-thickness articular cartilage defect with the dimensions 5 × 5 mm were as follows: three of four were detected on images produced at 1.5 T with an average confidence score of 85%, three of four were detected on images produced at 1.0 T with an average confidence score of 70%, zero of four were detected on images produced at 0.27 T, and zero of four were detected on images produced at 0.27 T (motion-corrected sequences). The lesion not detected on the 1.5-T and 1.0-T images was located on the palmar aspect of the condyle.

One lesion was correctly measured at 10 × 5 × 1 mm on the 1.5-T images. For the remaining detected lesions, the discrepancy in the measurement on the high field images ranged from 1 to 2 mm. The dis-
crepancy in the measurement of the detected lesions on the low field images ranged from 1 to 5 mm. The one subchondral bone defect with dimensions $5 \times 5 \times 1$ mm that was detected on the 0.27-T motion-corrected images was measured on the MR images as $5 \times 10 \times 1$ mm. Motion caused the lesion to appear longer, which resulted in the incorrect measurement and an increased confidence score. In addition to the lesions created, six separate lesions that were not correlated to ones that were created were identified using the 0.27-T images. These false lesions were not seen on the 1.0-T or 1.5-T images.

On the high field images, the PD FSE was preferred for lesion detection followed by the PD and T2 FSE, which were equally represented. On the low field images, the T1 weighted GRE was most commonly used; however, certain lesions were most apparent on the T2 FSE images. The lesions were not evident on the T2* GRE images from the low field system.

4. Discussion
This preliminary study shows that there is a difference in detection of subchondral bone and articular cartilage defects when comparing high and low field MR

Fig. 1. Sagittal images of a fetlock joint acquired with three different MR systems: 1.5 T, 1.0 T, and a 0.27 T with and without motion correction software (MI). The images shown were acquired with the sequence preferred by the readers for lesion identification: PD FS for the high field systems and T1 weighted three-dimensional (3D) GRE for the low field system. This fetlock has an osteochondral defect on the distal aspect of the third metacarpus palmar to the transverse ridge. This lesion is well visualized on the 1.5-T and 1.0-T images. The lesion can be identified on the 0.27-T standard image; however, it appears smaller and has an area of flattening as opposed to a defect. The 0.27-T MI image was acquired without any motion, and the lesion is not visible. The difference in the image acquisition parameters between the standard 0.27 sequence and the MI sequence obscured the lesion even though no motion was present on the study. On the low field images, the articular cartilage adjacent to the subchondral bone defect has been removed. However, the signal intensity in this region on the low field images is unchanged, and this would indicate the presence of articular cartilage.
systems. The largest difference was observed when evaluating articular cartilage defects, which were not identified on the low field images. The presence of motion further exacerbated the differences in lesion detection between the high and low field systems.

The motion produced in the low field images was intended to represent the swaying that occurs in standing, sedated horses. The small amount of motion created was intended to accurately create the conditions that occur when imaging the standing horse. In this study, motion did not allow accurate identification of the subchondral bone defects by obscuring them entirely or distorting the dimensions. However, most cases will have more motion than was created on this study with a greater negative impact on the image quality. The motion created did not simulate fetlock flexion that occurs in addition to swaying during image acquisition. Fetlock flexion is commonly observed in various degrees, and it creates choppy and abrupt motion; this will contribute motion artifact to the study. The result of the different types of motions on image quality is unknown.

Horses imaged while standing are positioned base wide because of the size of the magnet. This positioning creates an asymmetrical joint space with the side of the joint closest to the magnet being narrowed. Furthermore, weight bearing decreases the amount of synovial fluid between the articular surfaces. Compared with anesthetized studies, joints imaged with the horse standing have asymmetrical joint spaces with less synovial fluid. These characteristics complicate interpretation and are a disadvantage for lesion detection. This study alleviated these difficulties by creating even joints spaces and a consistent layer of synovial fluid in the joint space. The images made under these circumstances make lesions more visible compared with the images acquired in a standing horse.

In the authors’ clinical experiences, osteochondral lesions bordered by synovial fluid without an opposing articular surface are more easily identified compared with lesions with an adjacent articular surface. This did not correlate with the results in this study. The lesions on the distal aspect of the third metacarpus that were covered by the first phalanx were more easily identified than those on the palmar aspect of the third metacarpus. This difference between the study results and the authors’ clinical experience may be the result of the amount of saline adjacent to the palmar metacarpus. An intact joint has a thin layer of synovial fluid; this contrasts the specimens, which had a considerably thicker adjacent layer of saline. This may have saturated the gray scale or resulted in partial volume averaging, which falsely represents the presence of articular cartilage. The detected lesions on the low field standard images appeared smaller or as areas of flattening as opposed to defects. In addition to the discrepancy in the articular cartilage signal and lesion size, six false-positive lesions were detected on the low field images. Defects in the subchondral bone were detected on the images that did not correlate with a lesion. These findings substantiate concerns about the capability of the low field systems to accurately resolve articular cartilage and its interface with the subchondral bone. This subject requires further investigation.

5. Conclusions

Although high field systems may not translate into greater diagnostic accuracy for certain lesions, osteochondral defects challenge the resolving power of MR systems. The difference in lesion detection between the low and high field systems and the detection of false-positive lesions on the low field images illustrate this principle. Low field MR systems provide many advantages to equine patients with musculoskeletal disease. They provide a cost-effective system for advanced imaging to patients who would not otherwise have access to MR imaging. When correctly acquired, they produce diagnostic studies that allow for identification of osseous and soft tissue lesions. However, lesion size and contrast affects lesion appearance on all MR studies. Understanding the limitations of each system and the
impact of motion on image quality in standing exams is important when referring a case for MR imaging. Motion does significantly impact the image quality. A difference has not been observed by the investigators when comparing anesthetized feet studies with standing feet studies on the low field systems. A difference is commonly observed by the investigators when comparing anesthetized studies of the fetlock and more proximal aspects of the limb with standing studies. Until the limitations of each system are defined, extreme caution should be used when interpreting studies performed standing on the fetlock or more proximal in the limb, especially when the joint surfaces are a concern. Studies are needed to determine the critical lesion size for all types of osseous and soft tissue lesions and not just for osteochondral defects. Until the time that critical lesion size is determined and the motion-correction software is validated, general anesthesia in these cases is the best way to preserve image quality and prevent motion artifacts that would result in an inaccurate appearance of lesions (Fig. 1).

References
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