Magnetic Resonance Imaging of the Equine Stifle: 61 Clinical Cases

Since 2008, low-field magnetic resonance imaging (MRI) of the stifle has been performed on live horses at multiple veterinary institutions. This article discusses this new technique and summarizes MRI findings in 61 horses compiled from five equine veterinary practices.

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Despite routine use and growing popularity of MRI in equine medicine, the stifle remains a very difficult joint to examine via most available imaging modalities. Although MRI of the stifle has been reported in live horses using an ultra-short, wide-bore 1.5 T magnet system, clinical cases are not typically performed with this unit due to the difficulty of patient positioning and size limitations of most performance horses.[1,2] Over the past few years, however, there have been efforts by a group of practitioners at five different practice sites, each owning a low-field MRI system (Rotating Vet MR Grande XL, Esaote, SpA, Genova, Italy) to image the stifle in live performance horses (Figure 1). This report summarizes these efforts and reviews common clinical findings in 64 stifle examinations from 61 horses.

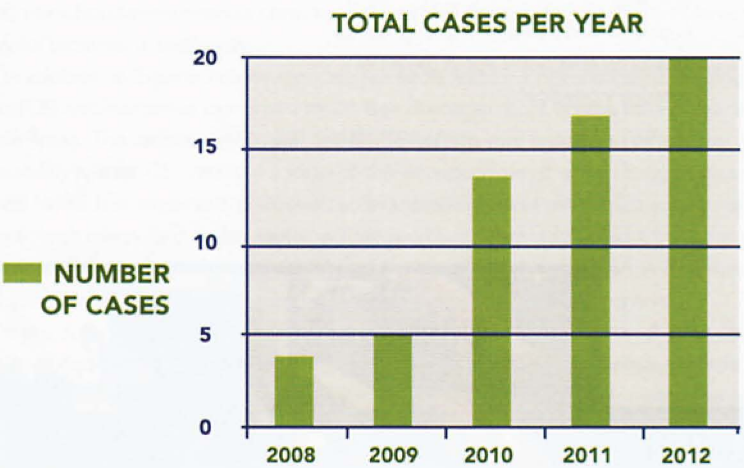


Figure 1. This figure illustrates the total number of equine stifle magnetic resonance imaging studies from all five participant veterinary institutions between 2008 to 2012.

MATERIALS AND METHODS

There are currently five institutions (four in the United States and one in Europe) that use the Esaote 0.25T Rotating Vet MR Grande XL MRI system to scan equine stifles of clinical cases. To perform a stifle MRI examination, the magnet must be rotated 90 degrees so that the bore is oriented vertically. All horses are scanned under general anesthesia in dorsal or lateral recumbency, with the hind limb of interest extended vertically so that the femorotibial joint is centered (or close) to the magnet isocenter. A flex coil is then wrapped around the dorsal aspect of the stifle (Figure 2). For most horses, MRI protocol includes PD- and T2-weighted sequences, short tau inversion recovery sequence (STIR), and an isotropic 3D gradient echo (GE) T1 sequence. Total acquisition time in the scanner is currently about 50 to 65 minutes. Together, the PD- and T2-weighted sequences (4 to 5 millimeters [mm] thick) are useful for assessing tendons and ligaments and evaluating the quality of collagen matrix in acute, chronic, and healed injuries. The STIR sequences (e.g., 4 to 5 mm) are highly beneficial for assessing bone lesions, while the 3D GE T1 sequence is very thin (e.g., 0.7 to 1.2 mm) and useful to assess articular, subchondral, and other fine bony detail.

Patient Selection

The horses in this retrospective case series are from each of the five practice sites that requested written interpretations from the author (15, 10, 13, 11, and 12 written stifle MRI interpretations, respectively, from each of the five practices). Beginning in the spring of 2008 to the writing of this article, MRI of the stifle was performed in a total of 61 clinical cases. The ages of the horses ranged between 2 and 19 years. The breeds included Quarter Horse (23), Warmblood (19), Thoroughbred (4), Standardbred (2), Saddlebred (2), Morgan (2), Friesian (1), and Tennessee Walking Horse (1); in seven of the cases, the breed was unspecified. There were 17 geldings and 10 mares; the rest of the cases were unspecified. The disciplines of each patient varied and were not always included in the patient history; however, the predominant disciplines among those cited were racing, dressage, jumping, eventing, Western pleasure, barrel racing, and cutting. The main reason given for the MRI request was acute or chronic lameness isolated to one (or both) stifles. One examination was requested by an owner for a horse without clinically identifiable stifle lameness. The MRI examinations were unilateral, with the exception of three bilateral studies. All patients were scanned live and recovered from general anesthesia, with the exception of one horse, whose clinical prognosis was poor and was euthanized on the table; therefore, this patient's MRI study was completed postmortem.

The current average number of stifle MRI cases per year among the five practice sites is about seven, ranging from 3 to 15 horses per year. Figure 1 illustrates the current total number of increasing cases per year for all five sites.

Proper case selection, preparation, and positioning are critical to safely perform a stifle MRI study. In addition to the cases reported in this study, MRI also was attempted on several particularly short-legged horses and ponies, but positioning attempts were aborted

Figure 2. Typical example of a horse undergoing magnetic resonance imaging of the stifle, positioned in lateral recumbency with a slight tilt toward dorsal recumbency.

Proper case selection, preparation, and positioning are critical to safely perform a stifle MRI study.

because the femorotibial joint could not safely be placed in the magnet isocenter. Another existing limitation that occasionally occurred was in very short, very well-muscled and/or overweight horses (frequently Quarter Horses and Haflinger ponies) with hind limbs not quite long enough to position safely, leading to undue pressure on the surrounding soft tissues of the dependent limb musculature.

Positioning Techniques

Throughout the 4.5-year duration of this report, each of the facility sites developed various techniques using different equipment to properly scan their cases, including unique and variable position devices to raise the upper limb to place the stifle into the magnet isocenter. Among these techniques, these practices found placement of the horse in lateral recumbency with a slight tilt toward dorsal recumbency most reliably allows a patient's pelvis to fit underneath the rotated magnet gantry (Figure 2). Also, they realized that if the table does not drop low enough, it will cause problems with positioning and place unnecessary pressure on the upper thigh musculature of the dependent limb. Since the stifle undergoing a scan is the suspended upper limb and is raised and extended by placing shanks around the pasterns and attached to a pulley or hook in the ceiling, these practices determined that tilting the side of the table upward supports the upper limb and effectively lowers the opposite side of the table so that the thigh musculature on the dependent limb can further drop out of the way of the gantry. This also helps to raise and position the upper stifle into the isocenter. With respect to positioning time, each practice reported a time requirement of approximately 10 to 15 minutes to position a patient in the scanner.

RESULTS

The clinical MRI findings from this review were quite varied, though there were commonalities (Table 1). Typical lesions are illustrated in Figures 3 through 11. Most images revealed evidence of osteoarthritis in one or both femorotibial joints, ranging from subtle/mild to severe (Figure 3). The articular cartilage and subchondral plate was best visualized on the thin 3D GE T1 sequence (<1.2 mm) and the multiplanar reconstructions. Chondromalacia was noted at the distal weight-bearing surface of the medial and lateral distal femoral condyles. This finding, initially not believed to be authentic pathology, was then confirmed arthroscopically on a series of horses. In each of these cases, the subchondral plate and the superficial articular cartilage signal were somewhat unremarkable, but the deeper cartilage layers had a subtle-to-mild decrease in the 3D GE T1 signal, consistent with soft, chondromalacia felt when probed during surgery.

Abnormalities of one or several meniscotibial ligaments (MTLs) also were frequently present in most of the stifles evaluated (Figures 4a and 4b). Abnormalities were slightly more numerous in the craniolateral and craniomedial MTLs than in the caudomedial MTL. Many of the pathologies were believed to be degenerative changes within the intrasubstance of the ligaments with varying degrees of margin fibrillations and intrasubstance degeneration, but discrete tears were also present. There was a subjective correlation between the MTL pathology and the degeneration of the femorotibial joints.

Discrete tears and additional degenerative pathologies were often seen in both the medial and lateral menisci, involving one or several horns (Figures 5 and 10a). The tears broke-out into either the proximal and/or distal border of the meniscus and could usually be seen in at least two planes on both the T2 and STIR sequences.

Signal abnormalities were also commonly noted in the cranial and/or caudal cruciate ligaments (Figures 6a and 6b). Abnormal T2 and STIR signals were frequently apparent at the distal tibial insertions of the cranial and (to a lesser extent) caudal cruciate ligaments. In one horse, the proximal half of the caudal cruciate ligament was not present, consistent with rupture.

Degenerative cystic lesions were frequently seen at sites of entheses (Figure 7), namely in the proximal tibia adjacent to the insertions of the craniolateral and craniomedial meniscotibial ligaments. Other generalized vascular and hyperemic reactions were seen in the distal femur and proximal tibia, particularly in horses with active arthropathies.

Other lesions identified were various bone marrow lesions (Figures 8 and 10b), articular femoral and tibial degenerative cystic lesions (Figures 9a and 9b), subchondral lesions (Figure 10c), medial and lateral collateral ligament desmopathies (Figures 11a and 11b), suspected enostosis-like lesions, and osteochondrosis. Several horses had floating tissue fragments and numerous cases had evidence of effusion (Figure 11a). The origin of the peroneus tertius tendon, as well as the distal patellar ligaments were frequently found to vary in signal and architecture, but often contained regions of hyperintensity on all pulse sequences in many horses. This common finding was believed to represent normal variation of fiber heterogeneity. Included is an example of a case of a horse with stifle lameness with radiographs depicting focal lesions (Figures 12a and 12b); however, much more extensive pathology was apparent on the horse's stifle MRI study (Figures 12c-12f).

The initial cases of MRI in this review were typically horses with chronic stifle lameness in which available diagnostic tests and attempted treatments were not successful.

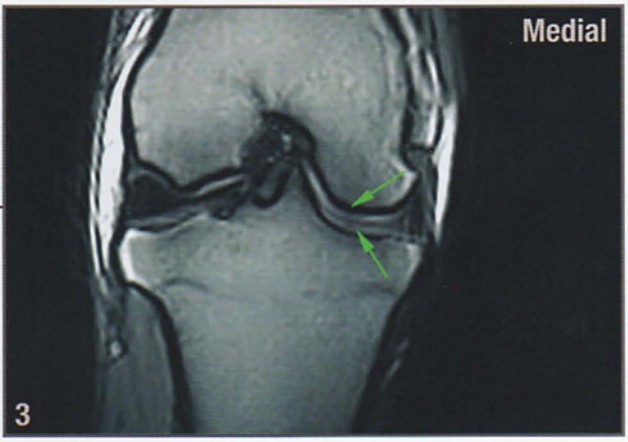
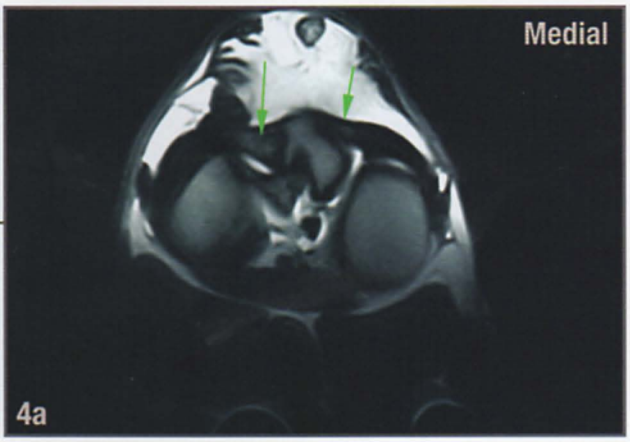
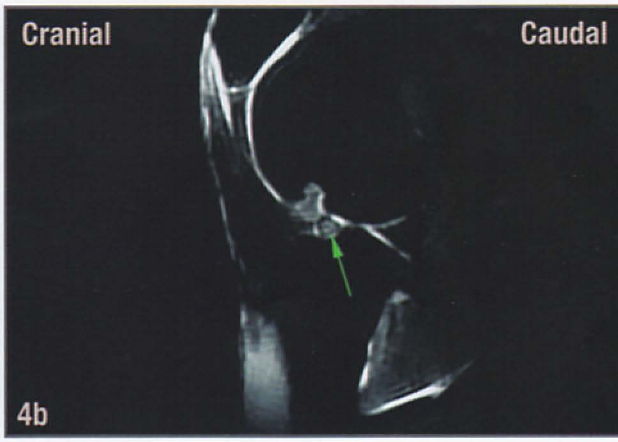


Figure 3. Mild Focal Cartilage Degeneration

Mild focal decreased articular cartilage signal at the weight-bearing aspect of the distal medial femoral condyle and the opposing proximal tibia (green arrows), suggesting mild cartilage degeneration.

Despite routine use and growing popularity of MRI in equine medicine, the stifle remains a very difficult joint to examine via most available imaging modalities.





Figures 4a and 4b. Meniscotibial Ligament Desmopathies

T2-weighted axial plane image (4a) shows an abnormal increased signal within the cranial lateral meniscotibial ligament and (to a lesser extent) the cranial medial meniscotibial ligament (green arrows). Sagittal STIR sequence (4b) confirms generalized increase in signal throughout the cross-sectional area of the cranial lateral MTL (green arrow).

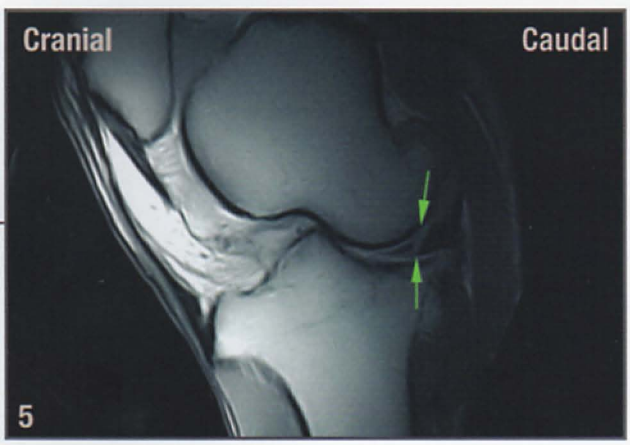
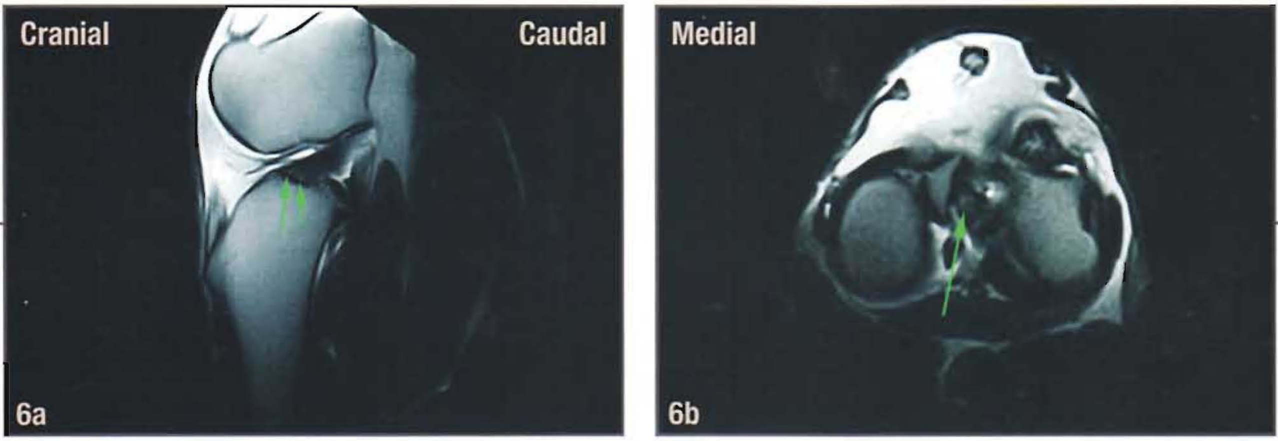


Figure 5. Meniscal Tear

PD-weighted sagittal sequence demonstrates a discrete tear breaking out at the proximal and distal articular surfaces of the caudal horn of the medial meniscus (green arrows).

Abnormalities of one or several meniscotibial ligaments (MTLs) also were frequently present in most of the stifles evaluated.



Figures 6a and 6b. Cranial Cruciate Ligament Injury

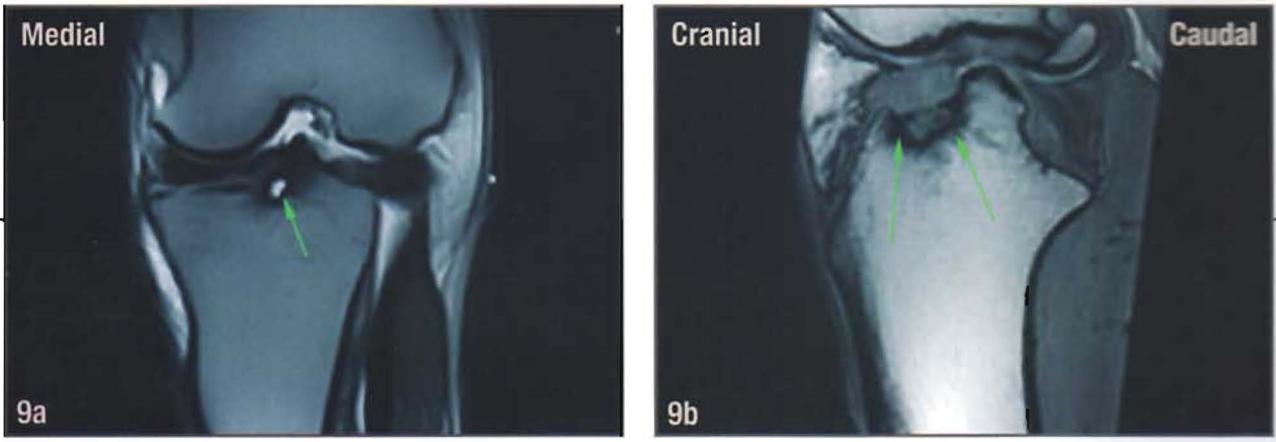
The T2-weighted sagittal sequence (6a) shows a striated increase in signal at the distal tibial insertion of the cranial cruciate ligament (green arrows), suggesting small fiber tearing. This pathology is confirmed in the T2-weighted axial plane (green arrow) (6b).

Figure 7. Enthesopathies

Dorsal plane 3D GE T1 sequence demonstrates a mild/moderate vascular reaction (vascular proliferation/neovascularization) at the proximal tibial insertion of the caudomedial meniscotibial ligament (green arrows), consistent with an enthesopathy.

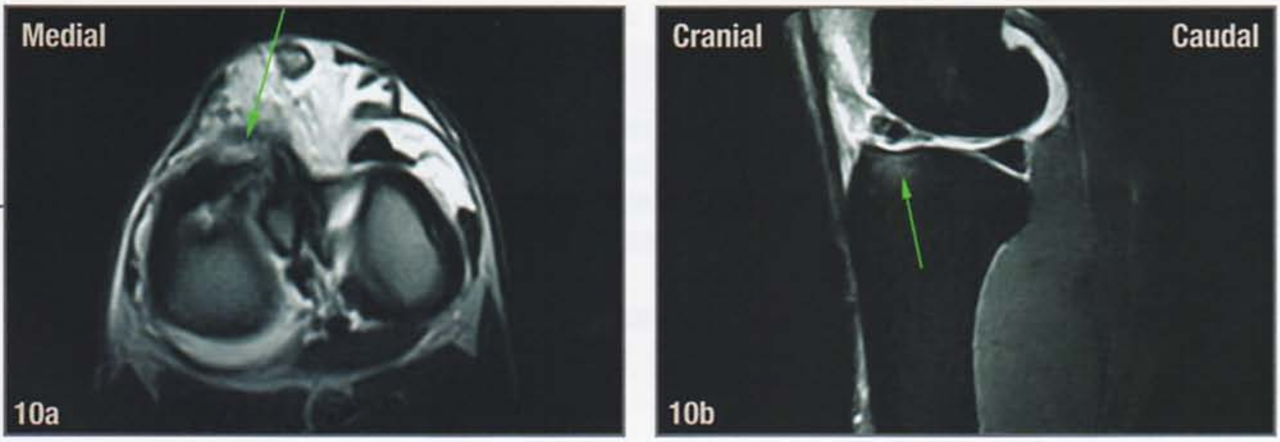
Figure 8. Tibial Crest Bone Edema

STIR sagittal image shows an increased signal within the subchondral and adjacent intramedullary bone of the tibial crest (green arrow), suspected to be stress injury. This lesion also corresponds with decreased T1 signal from fatty replacement.



Figures 9a and 9b. Degenerative Cystic Lesions

T2-weighted dorsal plane image (9a) shows a degenerative cyst-like lesion at the proximal tibial insertion of the cranial medial meniscotibial ligament (green arrow). This lesion is seen in the sagittal plane on 3D GE T1 (9b) as a large concave resorption (green arrows).



Figures 10a and 10b. Meniscal Tears, Bone Marrow Lesions

T2-weighted axial sequence (10a) shows marked tearing of the cranial horn of the medial meniscus and the cranial medial meniscotibial ligament (green arrow). An active, associated proximal tibial bone marrow lesion is also seen on the STIR sagittal sequence (10b) (green arrow).

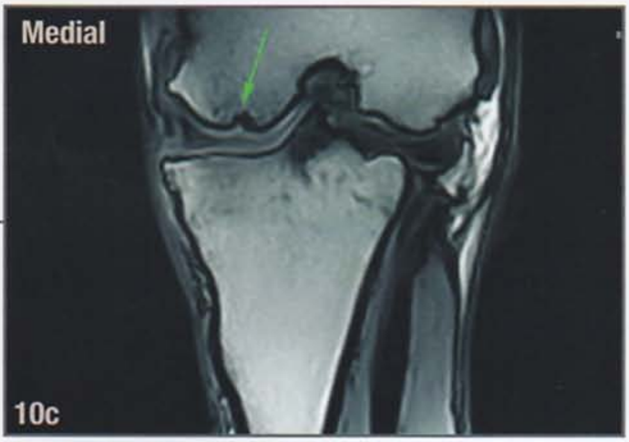
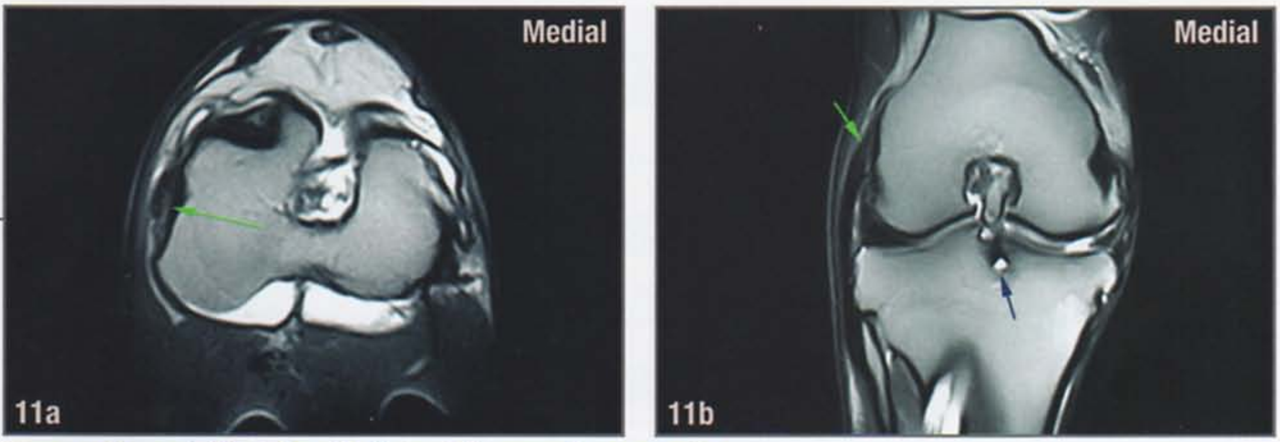


Figure 10c. Subchondral Defects

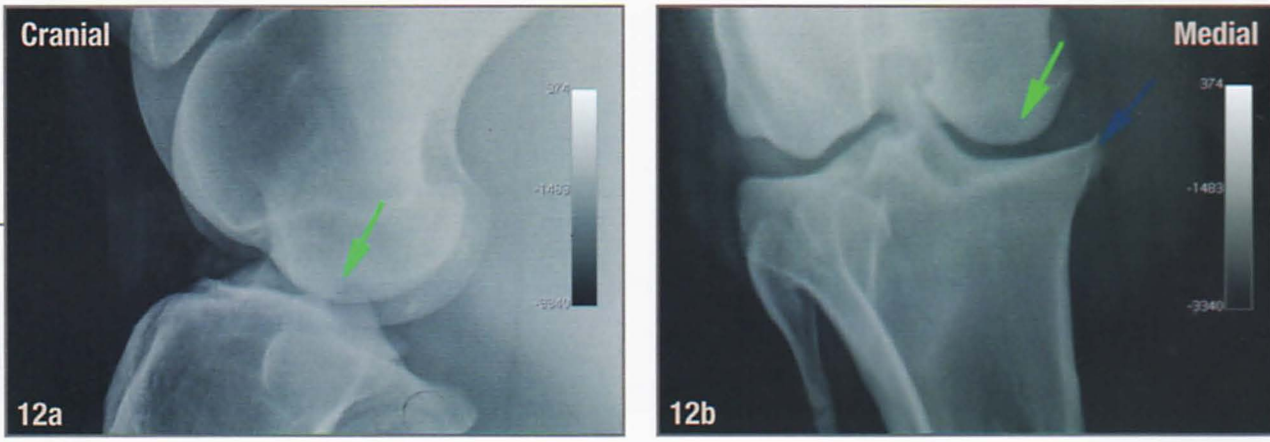
Patient also has a small subchondral defect at the weight-bearing aspect of the distal medial femoral condyle (green arrow).

Discrete tears and additional degenerative pathologies were often seen in both the medial and lateral menisci, involving one or both horns.



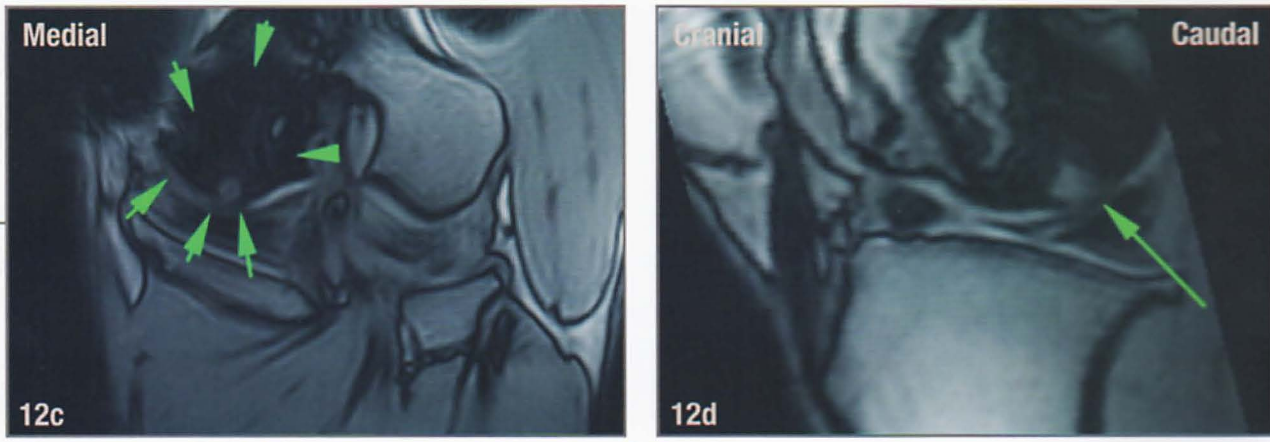
Figures 11a and 11b. Lateral Collateral Ligament Desmopathy

T2 axial and dorsal plane images (11a and 11b) show a mild/moderate heterogeneous increase in signal toward the femoral origin of the lateral collateral ligament of the stifle joint (green arrows). Also seen in the dorsal plane image (11b) are degenerative cyst-like lesions at the proximal tibia, adjacent to the insertion of the caudomedial meniscotibial ligament (blue arrow). The axial sequence also reveals effusions of the caudal pouches of the medial and lateral femorotibial joints.



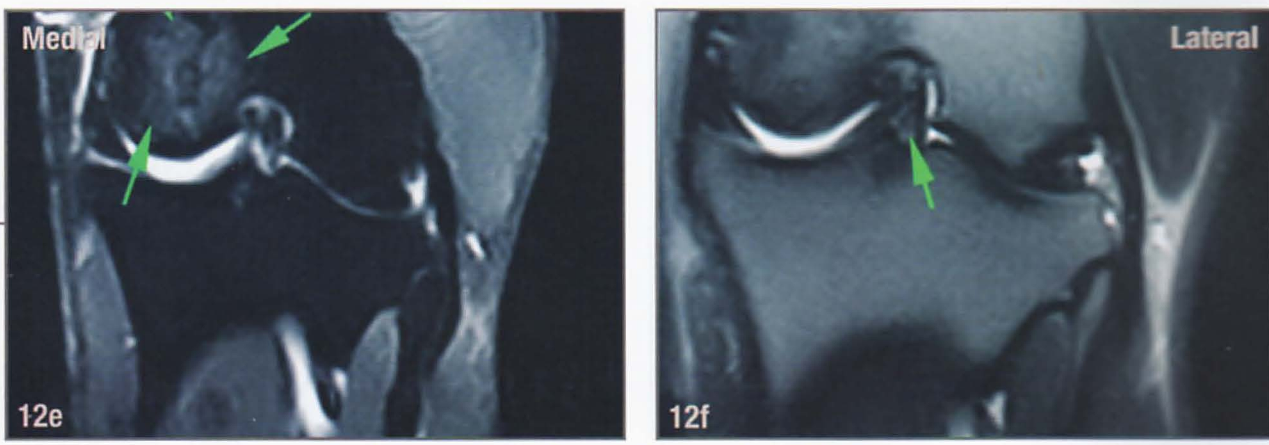
Figures 12a and 12b. Cystic Lesion

Lateromedial (12a) and caudocranial (12b) radiographs of an 8-year-old Quarter Horse mare's stifle suggest a cystic lesion (green arrow) of the distal medial femoral condyle with periarticular bone modeling (blue arrow) of the proximal medial tibia.



Figures 12c and 12d. Extensive Intramedullary Bone Pathology

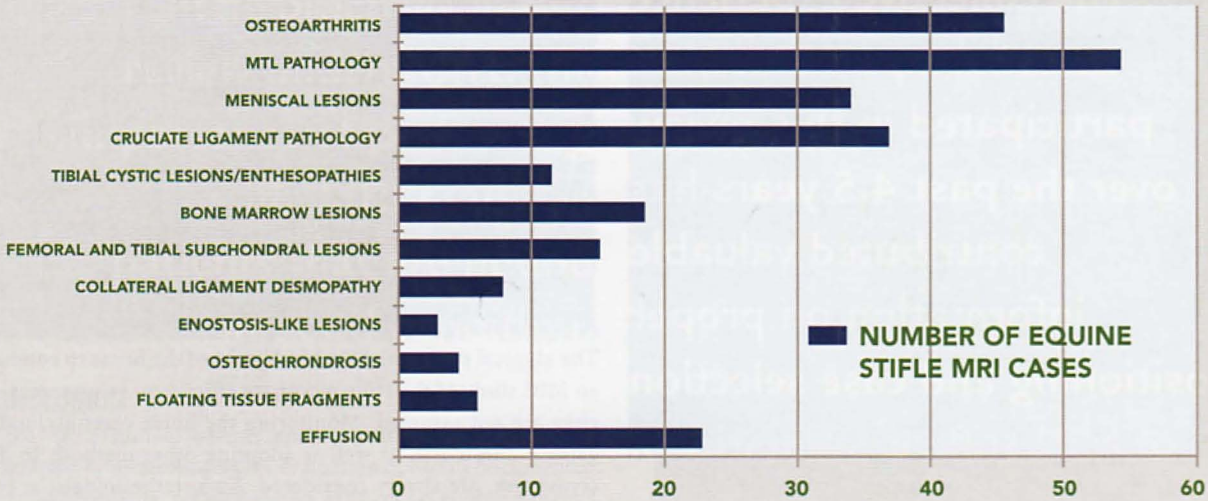
MRI images from this same 8-year-old Quarter Horse mare as Figures 12a and 12b: Dorsal (12c) and sagittal (12d) plane 3D GE T1 sequences reveal a cyst-like erosion of the distal medial femoral condyle breaking out into the medial femorotibial joint (long green arrow) that is surrounded by a marked amount of decreased T1 signal fatty replacement involving much of the intramedullary bone of the medial condyle (shorter green arrows). This extensive intramedullary bone pathology was much greater than anticipated given the initial radiographic findings.



Figures 12e and 12f. Extensive Intramedullary Bone Pathology and CCL Injury

MRI images from this same 8-year-old Quarter Horse mare as Figures 12a and 12b: The decreased T1 signal fatty replacement corresponds with a significant amount of intramedullary STIR signal emanating from the articular lesion (12e). Just proximally, there is also an extensive amount of circumferential STIR signal in a large 'halo' with additional characteristics suggesting avascular necrosis. Dorsal plane T2 weighted image (12f) also shows abnormal increased signal within the cranial cruciate ligament at the distal tibial insertional site (green arrow), believed to represent partial fiber tearing.

TABLE 1: TYPICAL FINDINGS FOR EQUINE STIFLE MRI EXAMINATIONS



Osteoarthritis in one or both femorotibial joints ranging from subtle/mild to severe (45/61 cases; 74%)

Meniscotibial ligament (MTL) pathologies (intrasubstance degeneration, margin fibrillations, discrete tears and/or rupture (53/61 cases; 87%)

Discrete tears and degeneration of **medial and lateral menisci**, involving one or several horns (34/61 cases; 56%)

Cranial and/or caudal **cruciate ligament pathologies** (intrasubstance degeneration, discrete tears and/or rupture) (36/61 cases; 59%)

Tibial degenerative cystic lesions/enthesopathies at insertions of meniscotibial ligaments (11/61 cases; 18%)

Bone marrow lesions (18/61 cases; 30%)

Articular medial and lateral **femoral and tibial subchondral lesions** (subchondral irregularities, defects, and cyst-like lesions (13/61 cases; 21%)

Medial and lateral **collateral ligament desmopathies** (6/61 cases; 10%)

Enostosis-like **intramedullary lesions** (1/61 cases; 2%)

Osteochondrosis (2/61 cases; 3%)

Floating tissue fragments (4/61 cases; 7%)

Effusion present (22/61 cases; 36%)

The collective experience of the practices that participated in this review over the past 4.5 years has contributed valuable information on proper positioning and case selection of MRI stifle examinations.

DISCUSSION

The stifle MRI examination, as with any elective procedure under general anesthesia, requires appropriate consideration of risk-to-benefit analysis. Each veterinary facility pioneering this MRI procedure accepted an increased risk to patients given minimal-to-no previously established safety record. The initial cases of MRI in this review were typically horses with chronic stifle lameness in which available diagnostic tests and attempted treatments were not successful. Proper patient selection is also imperative when using this technique.

Initial Complications

Following a series of successful examinations and recoveries among the small number of practitioners performing the examinations, an increased and growing comfort level of safety was achieved. Nonetheless, four of the five sites reported the following initial complications:

One site had a horse that developed a reperfusion injury of the dependent limb gluteal muscles 4 hours after standing. This horse was later found to have a clotting disorder and had been placed on the table with a small portion of the hind end slightly off the edge of the table. Upon more precise positioning of future cases, no additional problems were encountered over the past 3 years.

At another practice, during the first month of scanning, two horses developed transient gluteal muscle atrophy of the dependent limb after recovery. At that time, the hind end of these horses had also been positioned partially unsupported off the edge of the table. The positioning was then adjusted carefully for complete support in all subsequent cases and no additional problems have occurred at this practice site in the past 2 years.

A third clinic described one patient that became quite painful in the rear limbs, but worse in the upper limb after recovery. A nerve paralysis was suspected, but the horse was clinically normal within 1 hour of gabapentin administration. No additional issues were encountered in any other horses at this facility.

A fourth practice reported a neuropathy and several myopathies postrecovery. One case was a short, unfit Warmblood and the other cases were short, overweight Haflinger ponies. In all of these cases, the patients had all been nonworking for at least 1 year and had particularly short legs and large bodies, which caused increased stress and pressure on the lower limb during positioning. It has since been determined that these types of cases are not good candidates for stifle MRI examination. When bilateral stifle examinations were performed in 3 horses, the horses subsequently had difficulty standing after recovery; subsequently, bilateral examinations are no longer performed at the same time. No complications were recorded on more "typical" taller performance horse breeds during unilateral examination.

Anesthetic Considerations

The atypical position of the hind limbs of the horse to conduct an MRI study of the stifle mandates efficiency, so unnecessary risks are not assumed. Monitoring the horse carefully under general anesthesia, as well as adopting other methods to decrease risk, are always considered. An anesthesiologist at one practice commented on a significantly "smoother" anesthetic experience during MRI when patients were premedicated with a dose of methocarbamol the evening before the scan, theorizing the muscle relaxation effect from premedication improved muscular blood flow and thus, cardiovascular function. This protocol has since been adopted for all stifle MRI cases at this particular practice.

In addition, the practices in this review underscored the importance of performing stifle MRI scans on patients that are fit and in good condition. When a patient had been convalescent for an extended period, some of the practice sites emphasized the importance of exercising these horses on a treadmill (injury permitting) for a few weeks before MRI examination. Furthermore, some of the sites strongly advocate direct blood-pressure monitoring versus indirect pressure monitoring for stifle MRI evaluation to obtain more accurate readings. As with any procedure requiring general anesthesia, the greatest attention to safe positioning and anesthetic monitoring are paramount to minimizing risk of complications.

This new MRI technology is expected to create a growing interest in treatment options and successful outcomes in performance horses with specific stifle pathologies.

The practices in this review underscored the importance of performing stifle MRI scans on patients that are fit and in good condition.

CONCLUSION

While MRI of human patients' knees is often requested before radiographic or ultrasonographic evaluation due to its documented diagnostic benefits, performing an MRI on an equine patient's stifle is significantly more difficult, as demonstrated in Figure 2.[3] With the exception of very short-legged breeds, stifle MRI evaluation appears to be well tolerated in conditioned horses that are appropriately positioned. The information gained thus far in these cases has proved quite valuable for specific diagnoses, leading to focused treatment plans and improved outcomes and prognoses. This technology is also expected to create a growing interest in treatment options and successful outcomes in performance horses with specific stifle pathologies.

In this review, while only a few cases resulted in euthanasia and necropsies, a larger number had arthroscopies where correlation of accessible lesions was successfully obtained. This information, combined with consultations from radiologists specializing in evaluating human patients' knee MRI studies, and increasing information in stifle and general equine musculoskeletal MRI studies aided the author's description of MRI abnormalities.

Active MRI pathologies were called within ligaments, if abnormal T2 and STIR signal was present. Given the susceptibility of T1- and PD- weighted sequences to the magic angle artifact, these sequences were not solely used for assessing active injuries. Articular and subchondral abnormalities were called when a disruption in the 3D GE T1 signal of the cartilage and subchondral bone was present relative to more normal appearing areas of the joint and also not believed to be caused by partial volume averaging and background noise.

The collective experience of the practices that participated in this study over the past 4.5 years has contributed valuable information on proper positioning and case selection of MRI stifle examinations, generating greater confidence for more reliable and safer recoveries. Although the total number of 61 patients in this study is considered small, averaging only 12 horses per practice site, the five clinics that undertook this endeavor should be commended for their pioneering and ground-breaking efforts in successfully performing stifle MRI studies on typical performance horses.

A future article will detail the treatment plans and clinical outcomes of these horses with available follow-up information.

Acknowledgments

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Disclosure

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FUTURE REPORTS

A future article will detail the treatment plans and clinical outcomes of these horses with available follow-up information.

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