

# Usefulness of magnetic resonance imaging in the diagnosis of feline hip joint disorders

JOANNA GŁODEK, ZBIGNIEW ADAMIAK, PAULINA PRZYBOROWSKA,  
YAUHENI ZHALNIAROVICH

Department of Surgery and Radiology, Faculty of Veterinary Medicine, University of Warmia and Mazury,  
Oczapowskiego 14, 10-957 Olsztyn, Poland

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Głodek J., Adamiak Z., Przyborowska P., Zhalniarovich Y.

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### Summary

Magnetic resonance imaging (MRI) is an effective imaging modality used to investigate musculoskeletal disorders. This article reviews recent questions including indications, contraindications, artifacts, preparation patient and MRI protocols of imaging feline hip joints. The recommended sequences for imaging feline hip joints are: fat-suppressed three-dimensional spoiled gradient recalled acquisition in steady state (FS- 3D-SPGR), 3-D spatial spectral (SS) SPGR, T1-weighted 3D fast gradient recalled echo (T1-GRE), fat-suppressed T2-weighted fast spin echo (T2-FS), 3D fast imaging employing steady-state acquisition (FIESTA), proton density fat suppressed fast spin echo (PD FS-FSE). Interpretation of received images is also discussed. Due to a high number of cats affected by osteoarthritis and degenerative joint disease new diagnostics techniques are needed.

**Keywords:** magnetic resonance sequences, MRI, osteoarthritis, hip joint, cat

The identification of effective, reliable and non-invasive methods for examining feline joints significantly contributes to the development of modern diagnostic techniques due to a high number of patients affected by joint disorders (22). In human medicine, magnetic resonance imaging is the most popular and effective method of diagnosing the musculoskeletal system that supports imaging on different planes, provides good contrast between the analyzed structures and surrounding soft tissue, and does not involve ionizing radiation. It is used to evaluate the human joints for trauma, degenerative changes and inflammatory diseases, to detect abnormalities of articular cartilage, subchondral bone and associated with joint soft tissue structures (37).

### Indications

The most common disorders of the feline hip joint are dislocation, dysplasia and osteoarthritis. Most dislocations result from road traffic accidents, and the hip joint is usually displaced in the cranial direction. Hip joint dislocations are often accompanied by damage to the articular capsule, broad ligament and surrounding muscles (16). The frequency of dysplasia in feline populations is estimated at 7-23%, and it is more often noted in purebred cats (16, 23, 27). Osteoarthritis affects around 90% of the feline population (18, 24,

28). The terms „osteoarthritis” and „degenerative joint disease” (DJD) are used interchangeably, where the former applies solely to synovial joints, and the latter may also affect fibrous joints, including intervertebral discs (25).

DJD is diagnosed based on clinical symptoms and radiological changes (11). The following criteria: the presence of osteophytes, enthesiophytes or cysts, subchondral mineralization, subchondral sclerosis, subchondral erosion and ossification inside the joint (29). The above changes have been noted in both peripheral and axial joints in 93 out of 100 randomly examined cats (15, 28).

Mechanical loads applied to the cartilage play the key role in DJD, and their effect varies subject to the degree of joint wear, lubrication and friction inside the joint (6). Degenerative joint disorders were induced experimentally through immobilization (21), damage to the anterior cruciate ligament (20) and its excessive loading (31).

In cats, DJD has non-specific symptoms that are often overlooked by the animals' owners. They include lower levels of physical activity, reluctance to jump, decreased appetite, increased thirst and inability to find a comfortable resting position (17). During diagnosis, skeletal muscular disorders have to be first ruled out, in particular in older patients.

### Contraindications

The main contraindication for MRI is the presence of metal foreign bodies, such as surgical implants, metal sutures and wires or metal shavings deposited after surgery, which can produce artifacts due to differences in the magnetic susceptibility of various tissues (7). Foreign bodies can also become displaced, and they can lead to a local increase in temperature. The response is determined by the type of metal, field intensity and the applied sequence (9, 42). The presence of ferromagnetic and non-ferromagnetic substances leads to spatial disorganization and contributes to the formation of artifacts (14). The application of high field intensity MRI (HF-MRI) for imaging tissues with metal foreign bodies can lead to tissue damage due to local temperature increase. In low-field MRI scans, metal foreign bodies produce artifacts, but they do not pose a danger to the patient (26).

### Patient preparation

Patients undergoing an MRI examination should be immobilized and subjected to general anesthesia. Bodily movements, including chest movements caused by an elevated respiratory rate, can produce artifacts and lower the quality of the resulting images (42). General anesthesia may pose a risk, in particular in patients with cardiovascular disorders (19, 36). A full range of clinical tests, including blood morphology, blood chemistry and urine analyses, should be performed prior to MRI (17). During orthopedic examinations, special attention should be paid to joint mobility, presence of pain, crepitation and muscular atrophy (16).

The following anesthesia protocol is recommended for cats: general anesthesia induced with propofol IV (max 5 mg/kg), preceded by premedication with butorphanol IM at 0.2 mg/kg BW (1, 12, 36, 40).

The applied sequence affects the quality of the resulting images. Patient positioning, the choice of radio-frequency coil and imaging planes are also important considerations (42).

### Protocols for MRI scans of the hip joint

The sequences applied in humans, horses and dogs are used as models for MRI examinations of feline patients (2, 17, 32, 34). The animal is placed in a dorsal position with pelvic limbs abducted and rotated axially at an angle of 15-20°. The above position corresponds to the dorsoventral position that is commonly used in X-ray examinations (17). Hyperintensive synovial fluid can obscure the caudal region of the joint cartilage. The patient should be placed in the dorsal position to shift synovial fluid. Hip joints should be positioned centrally inside the coil for optimal image quality (22).

Various protocols have been recommended for MRI scans of the hip area. According to Guillot, a standard protocol should rely on sequences in two planes, including in the dorsal plane-fat-suppressed three-

-dimensional (3D) spoiled gradient recalled acquisition in steady state (SPGR, with repetition time TR of 42 ms and time echo TE of 8 ms), T1-weighted 3D fast gradient recalled echo (T1-GRE, TR 24 ms, TE 3 ms), fat-suppressed T2-weighted fast spin echo (T2-FS, TR 5418 ms, TE 81.5 ms), and in the transverse plane – 3D fast imaging employing steady-state acquisition (FIESTA TR 9.5 ms, TE 3.3 ms) and T2-weighted fast spin echo (T2-FS, TR 5418 ms, TE 81.5 ms). Gaps of 0 mm and slice thickness of 1 mm are applied in all sequences. The total time of the exam is approximately 60 minutes. The cited author suggested additional scans in transverse and sagittal planes for T2-FS and FIESTA sequences, but the above significantly prolongs the procedure (17).

The T2 FS-FSE sequence has also been suggested by Kamishina with a TR of 3687.5 ms and TE of 25 ms. The MRI protocol should also contain PD FS-FSE sequence with a TR of 3531.5 ms and TE of 9 ms. In the cited study, the MRI scan was performed under high field intensity (4.7 T) with slice thickness of 1.7 mm, gaps of 0.17 mm and total time of 30 minutes and 33 seconds for both sequences (22).

FS 3-D SPGR and 3-D spatial spectral (SS) SPGR sequences are also recommended for scans of feline hip joints (22, 41). These sequences also produce high-quality images of knee joint cartilage in human subjects.

Repetition time (TR) is the time in milliseconds between the beginning of successive excitation pulses with radio frequency, whereas echo time (TE) is the time in milliseconds between the moment the pulse is sent and a distinctive reflection peak is formed. Both parameters significantly influence tissue contrast in MRI (5).

The question of longitudinal magnetization (T1) and transverse magnetization (T2) is also important. Longitudinal magnetization is called spin-lattice relaxation, because it involves release of energy into the environment. Transverse magnetization is a spin-spin relaxation and it depends on individual interaction of magnetic fields of spinning nuclei. T1 and T2 value is different for various tissues. Generally on T1-weighted images rich protons tissue has high signal intensity and low signal intensity on T2-weighted images (5).

### Image interpretation

Images should be interpreted in view of differences in the anatomy of hip joints in dogs and cats. The feline pelvis is relatively narrow; obturator foramina are elongated; and the head of the femur is less deeply positioned in the acetabulum, which produces a smaller Norberg angle (30). In healthy cats, the Norberg angle reaches 95°. This physiological variation between species should not be interpreted as a symptom of dysplasia in MRI scans (16). Images of the opposite limb should be compared for a reliable diagnosis of hip joints (30).

In the imaging protocol proposed by Kamishina, joint cartilage with medium signal intensity is clearly contrasted against the hypointensive cortical bone and hyperintensive synovial fluid, whereas no distinctive contrast is observed between femoral cartilage and the hip acetabulum. Synovial fluid can partially obstruct the caudal region of femoral cartilage. In the PD FS-FSE sequence, the differences in the content of water molecules and, consequently, the number of protons determine the contrast between joint cartilage and the mineralized subchondral layer. In cats, the size, dimensions and position of hip joint cartilage significantly limit the usefulness of the T2-weighted FS-FSE sequence. The above sequence can be successfully used to examine advanced pathological states in DJD, whereas early stages of the disease may remain undiagnosed (22). The T2-FS sequence exposes areas affected by BML (bone marrow edema-like lesions) as distinct and hyperechogenic regions. High signal intensity and distinct surface contours in the above sequence can suggest the presence of cysts. In T1-GRE and SPGR sequences, cartilaginous osteophytes appear as hypointensive structures with irregular shapes. They are positioned on the acetabular margin and on the head and neck of femur. Subchondral sclerosis appears as a hypointensive area in the T1-GRE sequences and as a hyperintensive area in the SPGR sequence (17).

Similarly to T2-FS, the FIESTA sequence is used to evaluate changes that accompany osteoarthritis, diagnose joint hematomas and, partially, BML (17).

### Artifacts

Artifacts can lead to low image quality, false-positive findings and incorrect interpretation of the pathology (3, 33). The magic effect phenomenon and spurious signals with short echo times are typical MRI artifacts during examinations of the musculoskeletal system. Both errors are characteristically noted in structures made of collagen fibers, including cartilages, ligaments and tendons (33). Collagen structures in those structures are highly organized. Healthy tendons and ligaments emit low-intensity signals. If fibers in a static magnetic field are oriented at an angle of 55°, signal intensity will be high, leading to the identification of false-positive pathological changes such as degeneration or tear. The above is known as the magic effect phenomenon (35, 38). A short echo time also increases signal intensity in anisotropic structures. Sequences with longer echo times or changes in the patient's position are recommended to eliminate artifacts in images of the musculoskeletal system (33).

Disler lists three types of artifacts characteristic of joint cartilage: chemical shift, truncation and the magic angle phenomenon (10). The chemical shift is caused by a small difference in the excitation frequencies of water and fat protons. The areas where water and fat tissue overlap are characterized by high signal intensity, and their separation leads to a drop in signal

intensity (33). Chemical shift artifacts are most often observed in sequences with a narrow frequency band (3). They can be eliminated with the use of sequences that suppress the fat signal (39). The fat signal can be suppressed through fat saturation, inversion-recovery imaging or opposed-phase imaging. The choice of the most appropriate method is determined by the quantity of fat in the examined tissue (8). Truncation (Gibbs phenomenon) produces MR images with apparently laminar cartilage. This artifact results from fluctuations in signal intensity, and it is observed in regions with high contrast between tissues (13). In images of joint cartilage, this contrast is particularly visible in the 3D SPGR sequence. In this sequence, cartilage layers can be correctly identified based on differences in transverse relaxation time (T2) between cartilage plates (10). According to Kamishina, the laminar division produced in FS-3D SPGR and FS-FSE sequences corresponds to the arrangement of proteoglycans (22). The underlying causes of artifacts have to be identified and explained to avoid, minimize and eliminate imaging errors (4).

### Conclusions

Feline joints are diagnosed by MRI methods based on human models and sequence protocols applied in other animals. Due to anatomical differences and the small size of diagnosed structures in cats, new diagnostic methods are required, in particular for examinations of shoulder, elbow and stifle joints.

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Corresponding author: lek. wet. Joanna Glodek, ul. Oczapowskiego 14, 10-957, Olsztyn; e-mail: j\_glodek@wp.pl