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The use of gadolinium-containing medium dilutions in evaluations of pathological changes in magnetic resonance images of the canine elbow

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Abstract

The aim of this study was to evaluate the usefulness of the paramagnetic gadolinium-containing contrast agent, diluted 1:800, in evaluations of pathological changes in the canine elbow joint. The experiment was performed on 6 large breed dogs of both sexes with a body weight of 25 to 40 kg. Thoracic limb lameness and pain in the elbow joint area were observed in all patients. The animals were subjected to standard physical examinations, radiography and low-field magnetic resonance imaging scans with the use of a contrast agent. The Spin Echo T1 dorsal sequence as well as 3D SST1 transverse and XBONE T1 transverse sequences were highly effective in diagnosing osteochondritis dissecans (OCD) of the medial humeral condyle. Degenerative changes and the fragmented coronoid process (FCP) of the ulna were very well visualized by High Resolution Gradient Echo, XBONE T2 and Spin Echo T1 sequences in the sagittal plane. The administration of the gadolinium contrast agent, diluted 1:800, to the elbow joint cavity enhances the diagnostic value of magnetic resonance images in evaluations of medial compartment disease, in particular fragmentation of the medial coronoid process.

MRI, arthrography, contrast agent, dogs, elbow

Thoracic limb lameness caused by pathological changes in the elbow joint is difficult to diagnose (Reichle and Snaps 1999). Magnetic resonance imaging (MRI) is a non-invasive and highly sensitive tool for evaluating soft tissues of the musculoskeletal system (Miller 1999; Snaps et al. 1999). This method is routinely used to diagnose pathological changes in the medial epicondyle in humans, and it is recommended when other techniques, such as radiography, ultrasonography and clinical examinations, fail to provide a clear diagnosis (Park et al. 2008). In human medicine, MRI is a method of choice for diagnosing lesions and diseases of the elbow joint and other joints with cavities (Dalinka et al. 1989; De Smet et al. 1990; Hayes and Conway 1992; Heron and Calvert 1992; Hodler et al. 1992; Recht 1994; Buckwalter 1996; Hill et al. 2000; Sahim and Demirtas 2006). According to Cook and Cook (2009), MR images are a source of additional information for diagnosing pathological changes in tendons and muscles in the area of the canine elbow joint. Canine elbow dysplasia was long diagnosed by radiography and arthroscopy. Today, older diagnostic methods are being gradually replaced by MRI (Adamiak et al. 2011). The standard MRI protocol for examining the elbow joint involves T1- and T2-weighted sequences in dorsal, sagittal and transverse planes (Adamiak et al. 2011; Zhalniarovich et al. 2014; Zhalniarovich et al. 2017).

The main aim of this study was to determine the diagnostic usefulness of the paramagnetic gadolinium-containing contrast medium, diluted 1:800 and administered to the elbow joint.

Materials and Methods

All patients included in this study were referred for assessment of unilateral forelimb lameness. The study was performed on 6 elbow joints of large breed dogs (6 client-owned dogs) of both sexes, including 3 German

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Shepherds, 2 Labrador Retrievers and 1 mixed-breed. The mean age was 3.3 years (7 months to 6 years), with a body weight of 25 to 40 kg, showing lameness in the thoracic limb. Clinical and orthopaedic examinations revealed that pain was localized in the area of the elbow joint. All animals were subjected to complete orthopaedic examinations; lateral, flexed lateral, and craniocaudal radiographic projections; and pre- and post-contrast MRI of the elbow joint. The contrast agent was gadolinium-containing medium (Omniscan, GE Healthcare, Princeton NJ, USA, 0.5 mmol/ml), diluted 1:800 and administered to the elbow joint cavity. Preliminary studies had revealed that the 1:800 ratio was the optimal dilution for MRI of the elbow joint (Zhalniarovich et al. 2017). Gadolinium was diluted 1:800 with the use of 0.01 ml (10 µl) of the Omniscan contrast agent and 8 ml of water for injection (Aqua pro injectione, Polpharma, Starogard Gdański, Poland). The contrast agent was administered to the elbow joint at the amount of 1–2 ml, and it was distributed evenly by flexing and extending the joint.

The patients were examined in a low-field (0.25 T) MRI scanner with a permanent magnet (Vet-MR Grande, Esaote, Genova, Italy) with the involvement of the ankle/foot DPA coil used in human medicine. For radiographic examination all the animals were premedicated. After radiographic modality all the patients were positioned inside the MRI coil. The elbow joint was scanned in three planes: dorsal, sagittal and transverse. Each patient was examined with the use of identical MRI sequences: Spin Echo T1 in the dorsal plane; High Resolution Gradient Echo, Spin Echo T1, and XBONE T2 in the sagittal plane; and XBONE T1 and 3D SST1 in the transverse plane. The scanning time was 35–40 min. The contrast agent was administered to the elbow joint cavity, and the above MRI sequences were repeated in every patient to determine the contrast agent's influence on the diagnostic quality of the resulting MR images. The obtained MR images were evaluated for intensity of surrounding elbow joint tissues, joint space brightness, homogeneous consistency and intensity of the contrast medium. All obtained images were subjectively interpreted by all co-authors (four people) of the publication blindly to each other.

Results

For all six joints and MRI sequences, the signal intensity was assessed for joint capsule, bone marrow, subchondral bone, articular cartilage, ligaments and contrast medium. Two dogs (33.3%) were diagnosed with osteochondritis dissecans (OCD) of the medial humeral condyle. Four dogs (66.6%) had fragmented coronoid process (FCP) of the ulna. In Spin Echo T1 and XBONE T2 sequences, there was a homogenous iso- to low-intensity signal of the subchondral bone and FCP compared to the surrounding muscles. The results of the study indicate that the Spin Echo T1 sequence in the dorsal plane was highly useful for diagnosing OCD of the medial humeral condyle. Degenerative changes in the medial condyle were also visualized in 3D SST1 and XBONE T1 sequences in the transverse plane (Plate IV, Fig. 1).

On the sagittal plane, the medial coronoid process and the medial aspect of the humeral condyle were clearly illustrated. On these planes the trochlear notch of the ulna and the anconeal process appeared smooth and curved. In sagittal and dorsal planes two opposing articular cartilages could not be seen separately. Our findings suggest that High Resolution Gradient Echo, XBONE T2 and Spin Echo T1 sequences in the sagittal plane are very useful for diagnosing degenerative changes and fragmentation of the coronoid process of the ulna (Plate IV, Fig. 2a). The joint capsule and ligaments had low signal intensity on all MRI sequences. The contacted cartilage surfaces were difficult to differentiate on all sequences.

On post-contrast MR images, the joint cavity was hyperintense compared to the signal for surrounding muscles. For 4 joints, a clearly hyperintense signal received from the gadolinium contrast agent was seen between the FCP and ulna (Fig. 2b).

The results of MRI scans revealed that the lameness was caused by degenerative changes of the medial humeral condyle of the elbow in two dogs and by FCP in the remaining four patients.

Discussion

The canine elbow is a hinge joint with an articular capsule that constitutes the articular cavity. In humans, MRI is used to detect loose cartilage bodies in joints and collateral ligaments of joints. Magnetic resonance exams can be performed with the use of a contrast agent to enhance the diagnostic quality of the test (Hill et al. 2000).

In veterinary medicine, MRI is still relatively rarely used in examinations of the elbow joint, and the literature on the subject is largely limited (Van Bree and Gielen 2008; Baeumlin et al. 2009; Cook and Cook 2009).

Our study indicates that the Spin Echo T1 sequence in the sagittal plane produces elbow joint images of low diagnostic value. The above sequence is also characterized by a short scan time. According to Baeumlin et al. (2009), the anatomy of the elbow joint can be visualized with high resolution when T1-weighted sequences are used. T2-weighted sequences produce less detailed images of elbow anatomy, but they effectively visualize cartilage defects. Our experiment suggests that XBONE T2 and High Resolution Gradient Echo sequences in the sagittal plane produce high-resolution images and support diagnoses of the fragmented medial coronoid process of the ulna. XBONE T1 and 3D SST1 sequences in the transverse plane can be effectively deployed to evaluate the articular cavity, surfaces of the elbow joint and osteochondritis dissecans of the medial humeral condyle. In Spin Echo T1 and XBONE T2 sequences, there was iso- to low-intensity signal of the subchondral bone and fragmented coronoid process compared to the surrounding muscles. Our results corroborate the findings of Baeumlin et al. (2009) who noted that MR examinations of the elbow joint also support detailed evaluations of the surrounding structures.

Dysplastic changes in elbow joints have not yet been fully explored (Cook and Cook 2009), which is why the term "medial compartment disease" is increasingly often used to replace "fragmentation of the medial coronoid process" (Gemmill 2013). As demonstrated in our study, osteochondritis dissecans is most effectively diagnosed in sagittal and dorsal planes in the form of loss of shadowing, flattened or irregular surfaces, or erosion of the medial condyle. Defects can reach the osseous layer of the condyle. According to Reichle and Snaps (1999) and Probst et al. (2007), MRI sequences in sagittal and dorsal planes are highly effective in diagnosing osteochondritis dissecans of the medial humeral condyle, but deliver far less detailed images of minor cartilage defects that do not reach sub-cartilaginous tissue. The above limitation can be attributed to the fact that cartilage is very thin in the discussed area. Soft tissue mineralization at the level of the medial condyle of the humerus can also point to dysplastic changes in the elbow joint (Grondalen and Braut 1976; Zontine et al. 1989; Walker 1998; Harasen 2003).

The results of an MRI examination of ununited anconeal process of the canine ulna were described in only one research study. The change was visualized in the sagittal plane, and it consisted of a groove between the anconeal process and the ulna (Reichle and Snaps 1999).

According to Carpenter et al. (1993) and Snaps et al. (1997), the detectability of pathological changes in the medial condyle of the humerus was estimated at 77% for MRI and 72% for radiography, whereas the detectability of the fragmented medial coronoid process was determined at 95.5% for MRI, 77% for radiography, and 86.7% for computed tomography. The above results indicate that MR is the most effective imaging technique for diagnosing pathological changes in the medial compartment of elbow joint. The administration of the contrast agent to the elbow joint cavity improved the diagnostic accuracy of MRI images. In this report, a solution of 0.5 mmol/ml of gadolinium contrast was used to outline lesions of FCP. The 1:800 dilution of the contrast agent was selected as optimal on the basis of a previous report (Zhalniarovich et al. 2017). The contrast agent delivered superior resolution in evaluations of degenerative changes affecting the medial compartment of the elbow joint, in particular the fragmentation of the medial coronoid process (Plate IV, Fig. 2b). Magnetic resonance arthrography delineates lesions of the FCP. The enhancement of the gadolinium contrast was obtained by extending the space between the joint cavity and the bone defect. Magnetic resonance arthrography is more helpful when bone defects are involving the subchondral bone (Snaps et al. 1999).

According to Beltran (1991) and Helgason (1997), the administration of the gadolinium contrast agent to joint cavities improves the visibility of pathological changes affecting the examined joints.

In our study, none of the patients experienced side effects resulting from the administration of the contrast agent. Hajek et al. (1990) concluded that gadolinium was a safe contrast agent for intra-articular injections administered to the joint cavity in rabbits.

Our report has some limitations. Firstly, the number of patients is small. Further studies on larger groups of dogs are needed to determine if the result remain the same. Another limitation is that the study involves only large breed dogs over 25 kg. Additional research on small breed dogs is required.

It can be concluded that low-field MRI was found to be a highly sensitive technique for diagnosing dysplastic changes in the medial condyle of the humerus and fragmentation of the medial coronoid process of the ulna. Unlike radiographic tests which often produce false negative results, MRI supports the acquisition of high-quality images that are easier to interpret and facilitate the diagnosis of joint defects at early stages of disease (Reichle and Snaps 1999).

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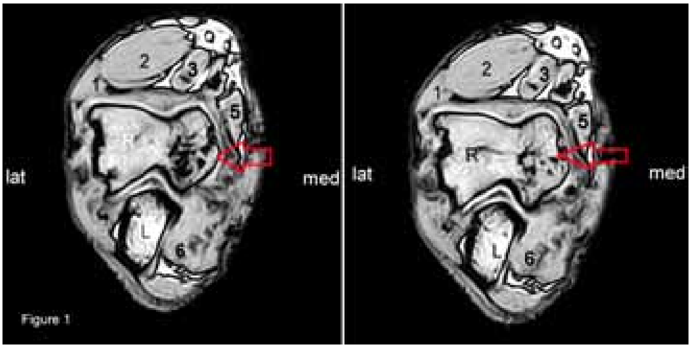

Fig. 1. Three-dimensional SST1 sequence in the transverse plane. Osteochondritis dissecans of the medial humeral condyle is marked with an arrow. Regenerating osseous tissue and osteophytes are visible on the medial side. R – humerus; L – ulna; 1 – extensor digitorum communis muscle; 2 – extensor carpi radialis muscle; 3 – brachialis muscle; 4 – biceps muscle; 5 – pronator teres muscle; 6 – flexor carpi ulnaris muscle.

Fig. 1

Fig. 2a. XBONE T2 sequence in the sagittal plane. Fragmented coronoid process (FCP) and the degenerative process in the elbow joint are marked with an arrow. R – humerus; L – ulna; P – radius; 1 – extensor carpi radialis muscle; 2 – biceps muscle; 3 – triceps muscle; 4 – flexor carpi ulnaris muscle.

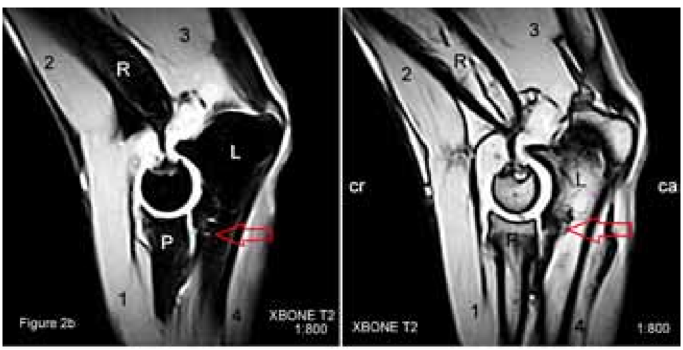

Fig. 2b. XBONE T2 sequence in the sagittal plane after the administration of the Omniscan contrast agent, diluted 1:800. Fragmented coronoid process (FCP) is marked with an arrow. The degenerative process in the elbow joint is visible. R – humerus; L – ulna; P – radius; 1 – extensor carpi radialis muscle; 2 – biceps muscle; 3 – triceps muscle; 4 – flexor carpi ulnaris muscle.