Direct magnetic resonance arthrography of the canine elbow

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Abstract

This study compares the effects of four dilutions of the gadolinium-containing contrast media (1:100; 1:400; 1:800; 1:1,200) administered to the elbow on the quality of magnetic resonance images. All the examined dilutions had a positive effect on image quality, and 1:800 was regarded as the optimal dilution of gadolinium for viewing the elbow because it imparted good contrast to the joint cavity without obliterating the contours of articular surfaces. Transverse, sagittal, and dorsal low-field magnetic resonance images were obtained in 24 canine cadaver front limbs. The musculus biceps brachii, m. triceps brachii, m. extensor carpi radialis, m. flexor carpi ulnaris, the articular surfaces, the medial coronoid process and the anconeal process of the ulna were well visualized by High Resolution Gradient Echo, XBONE T2 and Spin Echo T1 sequences in the sagittal plane. The biceps brachii, pronator teres, flexor carpi radialis, extensor digitorum communis, extensor carpi radialis, deltoid muscle and the articular surface of the medial condyle of the humerus were very well visualized by 3D SST1 and XBONE T2 sequences in the transverse plane. The triceps brachii muscle, extensor digitorum lateralis muscle, superficial digital flexor, deep digital flexor and the medial condyle of the humerus were very well visualized by the Spin Echo T1 sequence in the dorsal plane. This article describes for the first time the use of the gadolinium contrast agent administered to the canine elbow joint during magnetic resonance modality. Magnetic resonance arthrography can be a helpful visualization technique in treating canine soft tissue elbow injury.

MRI, contrast agent, gadolinium, dogs

Magnetic resonance imaging (MRI) is a method of choice for diagnosing elbow joint disorders in humans. It is one of the recently developed diagnostic techniques (Dalinka et al. 1989; De Smet et al. 1990; Hayes and Conway 1992; Hodler et al. 1992; Heron and Calvert 1992; Recht 1994; Buckwalter 1996; Hill et al. 2000; Sahin and Demirtas 2006).

In human medicine, MRI is used to diagnose free-floating fragments in joints, and it is highly useful in evaluations of collateral ligaments (Hill et al. 2000). The contrast agents can be administered directly to the joint cavity, which is an additional advantage of MRI (Hill et al. 2000). Diluted gadolinium-containing compounds are the most popular contrast agents for MRI (Tirman et al. 1993; Winalski et al. 1993).

Magnetic resonance imaging supports evaluations of the thickness and structure of articular cartilage. Minor damage to articular cartilage, the joint capsule and the surrounding soft tissues cannot be effectively evaluated by standard MRI. Contrast agents are administered by intra-articular injection to enhance the visualization of the joint cavity (Recht et al. 2005; Sahin et al. 2006; Gold et al. 2009). Magnetic resonance contrast agents all contain the paramagnetic component gadolinium, and their mechanisms are based on the same principle of physics (Kuriashkin and Losonsky 2000).

The first objective of this study was to compare the effect of four dilution levels of the gadolinium contrast agent (Omniscan) administered to the elbow joint cavity on the quality

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of MR images. The second objective was to determine the optimal level of gadolinium contrast medium dilution in MRI examinations of the canine elbow joint.

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Materials and Methods

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The study was performed on 24 elbow joints of 12 dogs of both sexes euthanized for reasons unrelated to orthopedic conditions or this study (4 German shepherds, 3 Labradors, 1 Doberman and 4 crossbreeds). All were aged 2 to 4 years, with body weights of 25 to 37 kg (mean weight 31 kg). None of the patients had a history of elbow joint disease. None of the dogs showed lameness of the front limbs for 8 weeks before euthanasia. During orthopedic examination, the limbs showed no pain and were within a normal range of motion. No evident abnormalities were observed over standard radiographic examinations. Both elbows of each dog were subjected to MRI immediately after euthanasia.

The patients were examined in a low-field (0.25 T) MRI scanner with a permanent magnet (Vet-MR Grande, Esaote, Italy), using the ankle/foot DPA coil used in human medicine. All patients were positioned in lateral recumbency with the elbow joint extended and centered in the middle of the coil. The elbow joint was scanned in three planes: sagittal, transverse and dorsal. Three sequences were selected in the sagittal plane: High Resolution Gradient Echo (TR 700-800 ms/ TE 18 ms), XBONE T2 (TR 900-1000/ TE 17-19 ms) and Spin Echo T1 (TR 700-900 ms/TE 18-20 ms). The Spin Echo T1 sequence was used in the dorsal plane. Two sequences were applied in the transverse plane: 3D SST1 and XBONE T2. In all sequences, slice thickness was 2 mm with 0 mm distance between slices. Scanning time was 35–40 min.

After standard MRI modality the examination was repeated with the use of the gadolinium contrast agent (Omniscan, GE Healthcare, USA, 0.5 mmol/ml) administered to the joint cavity at four dilution levels (1:100; 1:400; 1:800; 1:1,200) in 0.9% NaCl to determine the effect of the contrast agent on the quality of MR images. In conversion the molar concentrations were 5, 1.25, 0.625, 0.42, respectively. The contrast solution was administered at the amount of 1–2 ml, subject to the size of the visualized joint. After the administration of the contrast agent, the joint was extended and flexed for 60 s to distribute the solution evenly in the joint cavity. After 60 s, the elbow joint was placed inside the MRI coil, positioned, and scanned. For this contrast examination, the patients were divided into four groups of six elbows each. In subgroup 1, the contrast agent was diluted 1:100; in subgroup 2 – 1:400; in subgroup 3 – 1:800; and in subgroup 4 – 1:1,200. Images were evaluated for intensity of the contrast agent relative to the surrounding tissues, joint space brightness, and homogeneous consistency of the contrast medium. All obtained images were rated by all co-authors of the publication.

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Results

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The contrast agent administered to the elbow joint cavity improved the quality of the resulting images and enhanced the visualization of articular surfaces. All analyzed dilutions of the Omniscan contrast agent (1:100; 1:400; 1:800; 1:1,200) supported a more detailed examination of the elbow joint cavity. Omniscan dilution of 1:800 produced MR images of the most satisfactory quality. High Resolution Gradient Echo, XBONE T2 and Spin Echo T1 sequences in the sagittal plane proved to be highly useful for evaluating structures such as the medial coronoid process and anconeal process of the ulna and articular surfaces of the elbow joint. The contrast agent is injected to expand the joint space and produce hyperintense images. It enhances the visualization of articular surfaces, the joint capsule, and the surrounding soft tissues. Sequences in the sagittal plane are applied in examinations of the biceps brachii muscle, triceps brachii muscle, extensor carpi radialis muscle and flexor carpi radialis muscle (Plate IV, Fig. 1).

The administration of a contrast agent in the transverse plane (3D SST1 and XBONE T2) and the dorsal plane (Spin Echo T1) enhances the visualization of humeral condyles and their articular surfaces. The contrast agent fills the joint cavity and brings out the contours of articular surfaces. The biceps brachii muscle, pronator teres muscle, flexor carpi radialis muscle, extensor digitorum communis muscle, extensor carpi radialis muscle and deltoid muscle were also very well visualized by sequences in the transverse plane (Plate V, Fig. 2). The triceps brachii muscle, extensor digitorum lateralis muscle, superficial digital flexor and deep digital flexor were very well visualized by the Spin Echo T1 sequence in the dorsal plane (Plate V, Fig. 3).

The quality of MR images was enhanced even when the contrast agent was administered at the most diluted solution of 1:1,200. The contrast medium leads to the mechanical

widening of the elbow joint which is very tight in dogs. Gadolinium also provides additional contrast by adhering to articular surfaces and filling the joint cavity.

Discussion

Magnetic resonance imaging is a modern, non-invasive and highly sensitive diagnostic tool for evaluating articular surfaces and joint cavities (Konig et al. 1987; Solomon et al. 1989; Tervoven et al. 1993; Snaps et al. 1997; Miller 1999; Recht et al. 2005; Janach et al. 2006; Schaefer and Forrest 2006; Probst et al. 2007; Agnello et al. 2008; Gold et al. 2009; Jaskolska et al. 2013).

In our study, all analyzed dilutions of the contrast agent improved the quality of MR images. The contrast medium should be evenly distributed in the entire joint cavity. In the present experiment, this was achieved by flexing and extending the elbow joint for around 60 s. Image quality is determined by the time of joint manipulation after the administration of the contrast agent. Longer manipulation time can improve image quality (Reichle and Snaps 1999; Probst et al. 2007).

The biceps brachii muscle, triceps brachii muscle, extensor carpi radialis muscle and flexor carpi ulnaris muscle were very well visualized by High Resolution Gradient Echo, XBONE T2 and Spin Echo T1 sequences in the sagittal plane. Those sequences were also highly useful in evaluations of articular surfaces of the elbow joint, the medial coronoid process and the anconeal process of the ulna. The biceps brachii muscle, pronator teres muscle, flexor carpi radialis muscle, extensor digitorum communis muscle, extensor carpi radialis muscle and deltoid muscle were very well visualized by 3D SST1 and XBONE T2 sequences in the transverse plane. Those sequences also supported detailed visualization of articular surfaces of the medial condyle of the humerus. The Spin Echo T1 sequence in the dorsal plane was highly effective in diagnosing the triceps brachii muscle, extensor digitorum lateralis muscle, superficial digital flexor, deep digital flexor and the medial condyle of the humerus.

It was previously recommended to use the gadolinium solutions in MRI examinations (Tirman et al. 1993; Winalski et al. 1993). According to Van Bree et al. (1995) and Murphy et al. (2008), the administration of contrast to the joint cavity enhances the visibility of soft tissues and articular surfaces. In some works, the administration of diluted gadolinium supported detailed imaging of articular surfaces (Gray et al. 2008; Guermazi et al. 2008; Taylor et al. 2009). Schaefer et al. (2010) performed MRI scans of the canine shoulder joint by administering the diluted gadolinium contrast agent (1:100; 1:400; 1:800; 1:1,000; 1:1,200; 1:1,400; 1:1,600) directly to the joint. In the above study, 1:1,200 was the optimal dilution level which imparted very good contrast to the joint cavity and ligaments without obliterating the contours of articular surfaces (Schaefer et al. 2010). In our experiment, Omniscan (gadolinium) contrast agent delivered superior contrast resolution in examinations of the elbow joint. In this study, 1:800 was regarded as the optimal dilution level for a detailed evaluation of elbow joint anatomy.

Local safety proved to be superior after joint administration of gadolinium and rapid renal excretion took place (Schulte-Altedorneburg et al. 2003). An analysis of clinical studies spanning over 14 years (1987–2001), where gadolinium was administered to human subjects by intra-articular injection, revealed that Omniscan did not deliver toxic effects (Schulte-Altedorneburg et al. 2003).

Our results confirm the findings of other authors (Agnello et al. 2008; Murphy et al. 2008; Schaefer et al. 2010) who demonstrated that MRI is a highly useful tool for evaluating soft tissues and articular surfaces in examinations of the canine elbow joint. The administration of the gadolinium contrast agent significantly enhances the quality of MR images. In this study, 1:800 was regarded as the optimal dilution level for a detailed

assessment of elbow joint anatomy. Our outcomes agree with previous studies (Agnello et al. 2008; Murphy et al. 2008; Schaefer et al. 2010) that direct MR arthrography might be useful for the assessment of canine soft tissue elbow lesions.

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Plate IV
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Fig. 1. XBONE T2 sequence in the sagittal plane pre- and after contrast administration. Gadolinium-containing contrast medium is diluted 1 to 800. R – humerus; L – ulna; P – radius; 1 – extensor carpi radialis muscle; 2 – biceps brachii muscle; 3 – triceps brachii muscle; 4 – flexor carpi radialis muscle.
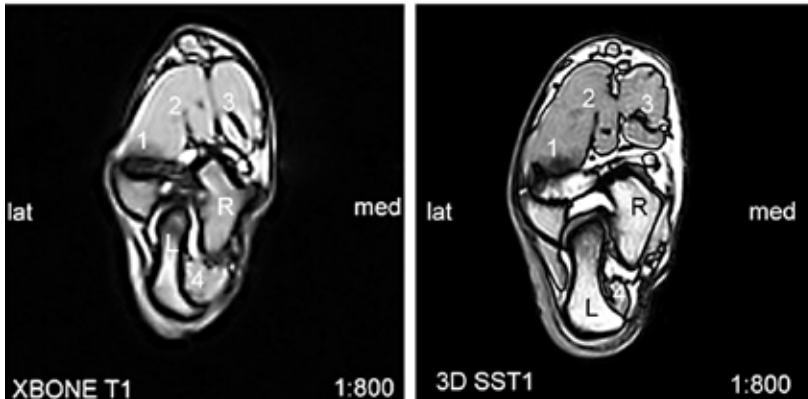
Plate V

Fig. 2. XBONE T1 and 3D SST1 sequences in the transverse plane after the administration of the gadolinium contrast agent diluted 1:800. R – humerus; L – ulna; 1 – extensor digitorum communis muscle; 2 – extensor carpi radialis muscle; 3 – deltoid muscle; 4 – biceps brachii muscle; 5 – pronator teres muscle; 6 – flexor carpi radialis muscle.
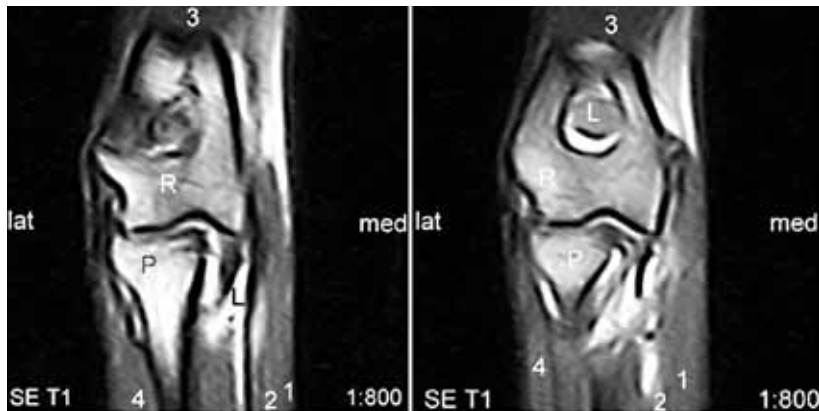

Fig. 3. Spin Echo T1 sequence in the dorsal plane after the administration of the gadolinium contrast agent diluted 1:800. R – humerus; L – ulna; P – radius; 1 – superficial digital flexor; 2 – deep digital flexor; 3 – triceps brachii muscle; 4 – extensor digitorum lateralis muscle.