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Review

Most commonly used sequences and clinical protocols for brain and spine magnetic resonance imaging allowing better identification of pathological changes in dogs

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Abstract

Magnetic resonance imaging is the best imaging modality for the brain and spine. Quality of the received images depends on many technical factors. The most significant factors are: positioning the patient, proper coil selection, selection of appropriate sequences and image planes. The present contrast between different tissues provides an opportunity to diagnose various lesions. In many clinics magnetic resonance imaging has replaced myelography because of its noninvasive modality and because it provides excellent anatomic detail. There are many different combinations of sequences possible for spinal and brain MR imaging. Most frequently used are: T2-weighted fast spin echo (FSE), T1- and T2-weighted turbo spin echo, Fluid Attenuation Inversion Recovery (FLAIR), T1-weighted gradient echo (GE) and spin echo (SE), high-resolution three-dimensional (3D) sequences, fat-suppressing short tau inversion recovery (STIR) and half-Fourier acquisition single-shot turbo spin echo (HASTE). Magnetic resonance imaging reveals neurologic lesions which were previously hard to diagnose antemortem.

Key words: magnetic resonance imaging, brain, spine, sequences, dog

Introduction

Pathological lesions and abnormalities of the brain and spinal cord are general neurological problems in dogs. Magnetic resonance imaging (MRI) is an excellent modality for diagnosing any neuropathologies which may occur in veterinary patients (De Decker et al. 2010, Dennis 2011, Gavin 2011, Suran et al. 2011, Adamiak et al. 2012). The present contrast between different type of tissues, such as soft tissues, fat, bone, fluids, provides the opportunity to diagnose various lesions without any contrast agents (d'Anjou et al. 2011, Robertson 2011). MR imaging reveals neurologic conditions which were previously difficult to diagnose antemortem (Gavin 2011). In many veterinary clinics, MR imaging has replaced myelography because of its noninvasive modality and because it gives excellent anatomic detail for surgical

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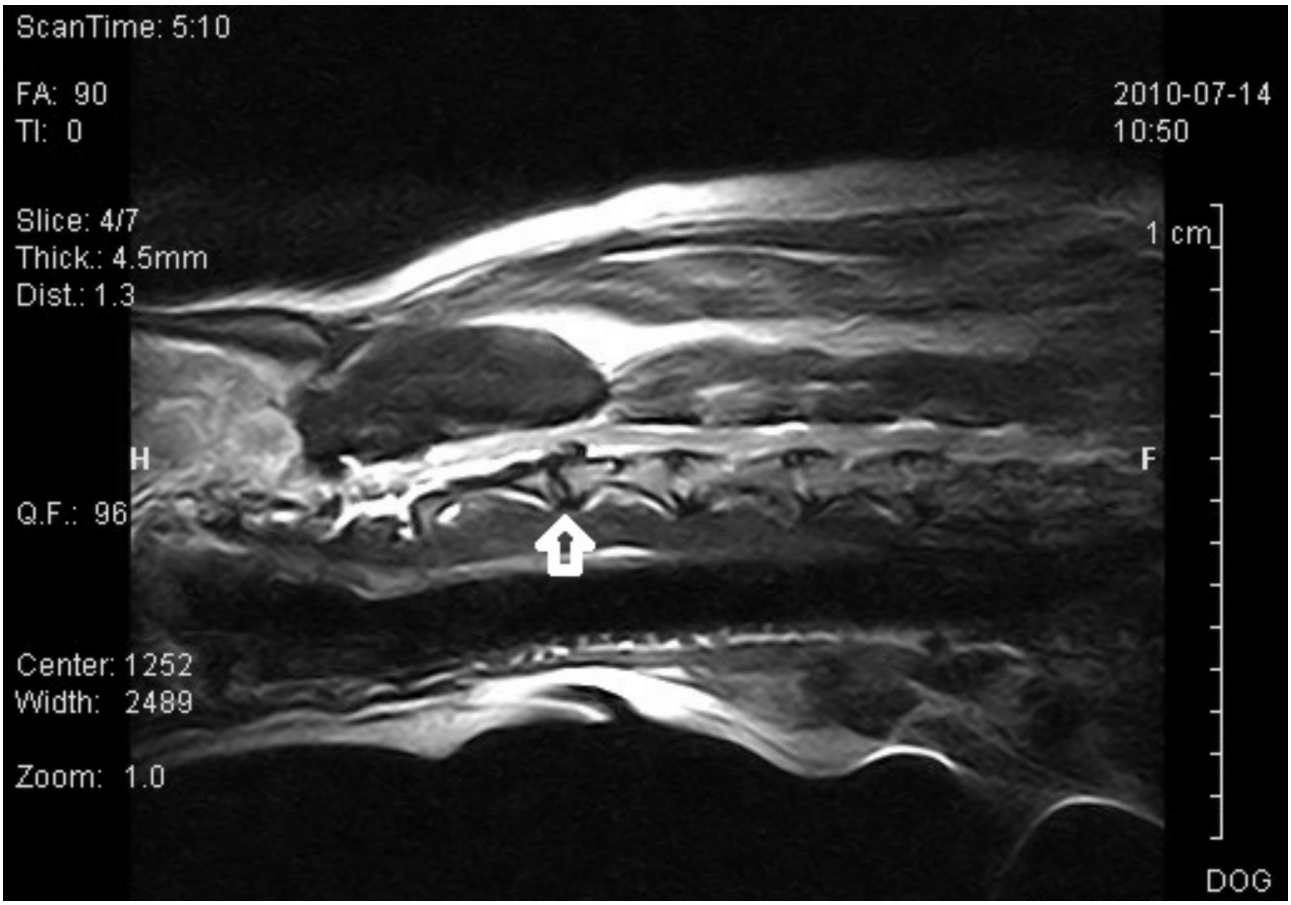

Fig. 1. T2-weighted Speed Spin Echo in sagittal plane image of disc compression between C3-C4 in a Basset Hound dog (arrow).

guidance (Parry et al. 2010, Pease et al. 2006). The aim of this study was to review indications and contraindications of MR, coil selection and positioning for scanning different areas, and the value of the most commonly used sequences in evaluating abnormalities in the canine brain and spinal cord, and to review different types of clinical protocols usually used in dogs.

Indications

Before performing the MRI modality, knowledge of clinical signs of the patient should always be interpreted. Clinical indications for brain or spine MR imaging include deformity, spinal or paraspinal pain, paresis or paraparesis, ataxia, paralysis, muscular atrophy, and epilepsy (Dennis 2011). There are different reports that have distinguished the MR signs in dogs with hydrocephalus, cerebellar degeneration, necrotizing encephalitis, granulomatous meningoencephalitis, infarcts, age-related degeneration, spinal cord hernias, wobbler syndrome, arachnoid cysts, syringohydromyelia associated with Chiari-like malformation in the Cavalier King Charles spaniel (Fig. 1), discospondylitis, atlantoaxial instability, meningeal calcification, hydromyelia, mechanical damage, and brain and spinal tumors (Vullo et al. 1997, Gonzalo-Orden et al. 2000, Kimotsuki et al. 2005, Besalti et al. 2006, Cherubini et al 2006, Garosi et al. 2006, Okada et al. 2006, Matiasek et al. 2007, Couturier J et al. 2008, Sturges et al. 2008, Carrera et al. 2009, Cerda-Gonzalez S et al. 2009, Young et al. 2009, Adamiak et al. 2011, Gavin PR 2011, Kwiatkowska and Pomianowski 2011).

Contraindications

Contraindications for MR imaging include the presence of metal close to the region to be scanned or the presence of metallic fragments from drill bits, which may remain after surgery. In addition, the presence of metal causes the formation of artifacts, risk of movement, local heating, and distortion of the image. However, much depends on the type of metal, field strength and MR sequences used (Dennis 2011).

Coil selection

Signal intensity decreases with increasing distance from the coil, therefore the investigated area should be as close as possible to the coil surface to maximize signal to noise ratio (SNR). There are three types of coil: transmit only coil, receive only coil, and transmit/receive coil. Radiofrequency Pulse (RF) coils have two functions: to transmit the RF pulse into the patient and to receive the RF pulse generated by the patient. These coils consist of multiple adjacent transmit/receive coils within the body of the magnet. Phased array coils are also transmit/receive coils (Dennis 2011, Robertson 2011). Dennis (2011) described phased array coils as ideal for medium and large dogs for examining the spine in dorsal recumbency. But these coils are inadequate for brain imaging because of the long distance between the patient's brain and the coil, which results in low signal reception (Robertson 2011). Dennis (2011) notes the option of using human phased array torso coils for dogs that have to be scanned in lateral recumbency and human extremity (knee) coils to scan the spine of small dogs and cats. According to Robertson (2011), the most commonly used coils in small animal brain imaging are volume coils, these coils transmit and receive the RF pulse. Surface coils are receive coils only, they can be flexible and therefore they can be wrapped around the investigated area. Such coils give good quality images because the area of interest is located very close to the surface of the coil.

Positioning

To receive a diagnostic MR image, the patient should be completely immobilized throughout the study. This is achieved by appropriate heavy anesthesia. Our observation is that the faster respiratory rates resulting from insufficient anesthesia result in poor quality MR imaging or cause artifacts. According to Dennis (2011) the best recumbency for scanning the spine is dorsal, in which the spine is close to the surface coil so the breathing motion is minimized. He also notes that large or narrow dogs may be scanned in lateral recumbency. The authors performed modality of the spine in lateral recumbency. Together with Dennis (2011) we are certain that the spine must be as straight as possible in the sagittal plane and should be repositioned if initial localizer images show curvature. Traction using weight may be applied to the neck of dogs with disc protrusion associated with cervical spondylopathy in order to assess the degree to which the lesion is dynamic (Penderis et al. 2004, Da Costa et al. 2006). A position that could put pressure on the spinal cord should be avoided, for example cervical ventroflexion in a dog with suspected atlantoaxial subluxation (Dennis 2011). We used ventral recumbency, to investigate the brain.

Protocol for brain imaging

There are many different combinations of sequences possible for spinal and brain MR imaging.

According to Robertson (2011), standard clinical protocol for the brain should contain the following precontrast sequences: T1- and T2-weighted turbo spin echo and Fluid Attenuation Inversion Recovery (FLAIR) sequences in the transversal plane, starting from rostral to the center of the first cervical vertebra (C1). Robertson (2011) and Wessmann (2006) used T2-weighted gradient echo sequence in the transverse plane to find blood degradation products in dogs with hypothetical hemorrhagic infarcts, hemorrhagic metastasis, coagulopathies or angiostrongylosis. A T2-weighted sequence in the sagittal plane is helpful in assessing transtentorial and foramen magnum herniation, and cauda fossa morphology.

Konar and Lang (2011) proposed that standard brain imaging protocol should include T2-weighted fast spin echo (FSE) in the transverse and sagittal plane, dorsal FLAIR, transverse T1-weighted gradient echo (GE) or spin echo (SE), and dorsal T1-weighted high-resolution three-dimensional (3D) sequences, both before and after contrast administration. Assuming that one sequence takes an average 6 min, this results in a total of 48 min for this protocol. Generally, SE sequences are used only for T1-weighting imaging, whereas the FSE technique is used for T2-weighting or proton density weighted imaging. FSE sequences require shorter scan times, and the obtained images have high resolution and fluid contrast (Westbrook et al. 2005, Sage et al. 2006, McRobbie et al. 2007).

Tidwell (2011) noted that if acute stroke is suspected as a minimum T2-weighted, pre- and postcontrast T1-weighted SE, FLAIR, T2-weighed GE, and perfusion-weighted MR imaging should be performed. Perfusion-weighted sequence must be the first of any gadolinium-enhanced sequences.

Benigni et al. (2005) note that after performing T2-weighted images additional FLAIR images should be performed in order to detect different occult brain lesions, such as those with a small lesion close to CSF; for example, paraventricular and meningeal lesions in animals with inflammatory disease. According to Cherubini et al. (2008) FLAIR sequences have higher sensitivity than T2-weighted images and precontrast and postcontrast T1-weighted images in detecting subtle

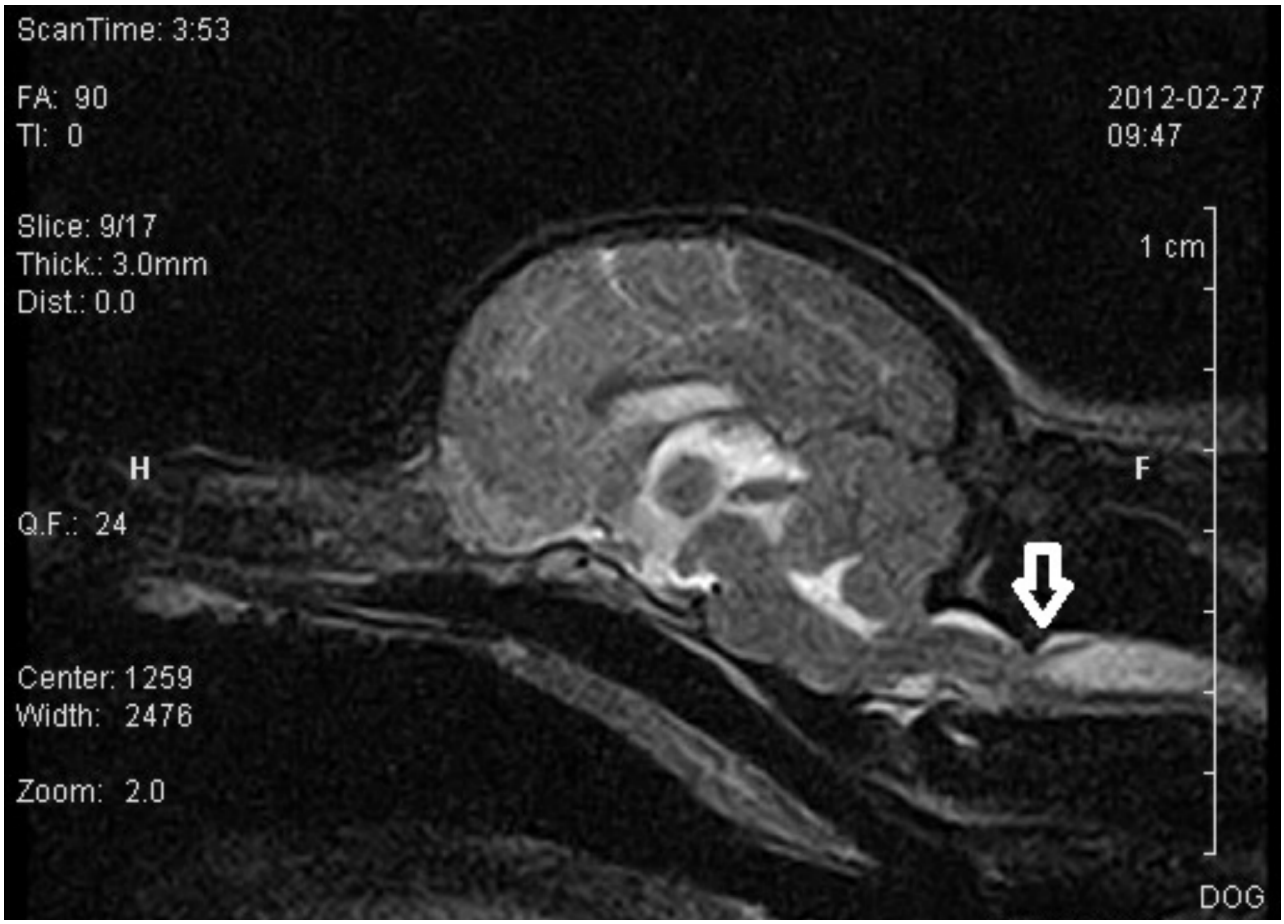

Fig. 2. T2-weighted Fast Spin Echo in sagittal plane image of syringohydromyelia associated with Chiari-like malformation in a Cavalier King Charles Spaniel.

lesions in dogs with multi-focal intracranial neurolocalisation which would otherwise be missed. FLAIR images can also provide additional visibility of lesions with high signal (hyperintense) on T2-weighted images which must be distinguished from Cerebrospinal fluid (CSF) (Benigni et al. 2005, Cherubini et al. 2008, Konar and Lang 2011), such as dermoid and epidermoid cysts, arachnoid cyst and cystic meningioma. On the other hand there are some lesions less visualized in FLAIR images in comparison to T1- and T2-weighted spin echo images, for example old cerebral infarcts, leptomeningeal metastasis and multiple sclerosis plaques in the basal ganglia and brain stem. In addition, a very important disadvantage of FLAIR sequence as noted by Benigni et al. (2005) is that it is prone to artifacts that could be misinterpreted. In summary, the authors and Cherubini et al. (2008) suggest that FLAIR images should be widely used for brain MR imaging study in dogs. FLAIR sequences are a long duration technique, because they require a long inversion and repetition time. It takes between 6 and 8 min to receive a high-resolution MR image (Konar and Lang 2011).

Fat suppression has performed by Konar and Lang (2011) using the short tau inversion recovery (STIR) sequence or the Dixon fat-water separation technique. STIR can be used to obtain excellent white/gray matter tissue contrast. STIR is a strong fat-suppressing technique with high sensitivity for fluid and pathology (Delfaut et al. 1999, Bitar et al. 2006). The Dixon fat suppressed technique uses the differences in precessional frequency of water and fat protons to achieve two or three echoes at a different time (Dixon 1984, Tien 1992, Zhang et al. 1996). At one moment in time, water and fat are in phase and their signals add, although at another time they are out of phase and their signals cancel. Fat suppressed image sequences can be acquired as T1-weighted or T2-weighted. Both provide a good signal to noise ratio (SNR) and resolution. Such sequences used with T1-weighting after contrast administration are highly sensitive for contrast uptake in lesions surrounded by fat, for example in the brachial plexus (Konar and Lang 2011).

The visibility of gadolinium-enhanced (after gadolinium administration) lesions increases with increas-

ing magnetic field strength, therefore it has been proposed to double the standard human dose of 0.1 mmol/kg body weight (BW) when using a magnetic field strength of <0.5T (Marti-Bonmati et al. 1997, Brekenfeld et al. 2001, Desai et al. 2003). Konar and Lang (2011) recommend 0.15 mmol/kg BW.

According to Cherubini et al. (2005), performing T1-weighted MR imaging after contrast administration gives better results in the diagnosis of a variety of brain lesions. For optimal assessment of gadolinium enhancement, the sequences should be performed with the same parameters as the T1-weighted precontrast sequences. An MR study of the brain is incorrect without postcontrast images (Robertson 2011).

Protocol for spine imaging

According to Dennis (2011), the standard clinical protocol for the spine should include T2-weighted images in the dorsal plane, for diagnostic reasons and for exact placement of sagittal slices; T2-weighted images in the sagittal plane; transverse T2-weighted images of any suspected lesions identified in the dorsal or sagittal plane; pre- and postcontrast T1-weighted images (eventually with fat suppression) and/or GE images, depending on the suspected nature of abnormalities; in dogs with symptoms of pain and no visible spinal abnormalities, STIR images are required in the dorsal plane to look for paraspinal soft-tissue pathology (Fig. 2).

Konar and Lang (2011) proposed a minimal spine protocol which includes T2-weighted in the sagittal plane and transverse 3D Hyce. In each case STIR in the dorsal plane must be included to eliminate bone marrow and muscular pathologies, which may not be noted in the other two sequences. More detailed examination of the spine may include transverse T2-weighted images (generally for intramedullary lesions), transverse T1-weighted SE and dorsal high-resolution 3D images before and after contrast agent administration.

Pease et al. (2006) noted that to obtain a true view of compression of the subarachnoid space the half-Fourier acquisition single-shot turbo spin echo (HASTE) should be used. HASTE sequences are heavily T2-weighting with the whole signal coming from pure fluids (McRobbie et al. 2003). Morphology of the subarachnoid space and some mass lesions can be less conspicuous in sagittal T2-weighted fast spin-echo than in HASTE images.

The breadth of neoplastic inflammatory infiltration into the vertebral bone marrow, paravertebral soft tissues, or epidural space is best assessed with fat-suppressed contrast-enhanced T1-weighted sequences (Tien et al. 1992, Georgy et al. 1994, Colosimo et al. 2006). Fat suppression can be achieved using STIR imaging, opposed phase imaging, and chemical (spectral) fat saturation. STIR imaging weakens the signal from fat by using the differences in T1-relaxion times of water and lipids. Opposed phase fat suppression is based on the phase differences of lipid and water protons in gradient echo images acquired at different echo times (Georgy et al. 1994, Delfaut et al. 1999).

MR imaging is an established modality in people with discospondylitis (Dagirmanjian et al. 1999, Stabler et al. 2001, Forrester 2004, Tali 2004, Govender 2005). MR imaging provides better visibility in early discospondylitis which may not be visualized by radiography. This examination allows the recognition of the exact location and extension of the infection. The vertebral bodies involved are hyperintense in STIR images compared with normal bone marrow, in T2-weighted images vertebral bodies can be hyperintense or hypointense, and in T1-weighted images the affected vertebral bodies have low signal intensity in comparison to normal bone marrow. The intervertebral disks concerned are isointense compared to normal disks in T1-weighted images, hyperintense in T2-weighted images, and in STIR images are also hyperintense (Carrera et al. 2011)

In summary, the magnetic resonance imaging technique is the method of choice for brain and spine pathologies. This modality provides high quality images and aids accurate diagnosis.

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