Advances in High-Field MRI

Adrien-Maxence Hespel, DVM, MS[a], Robert C. Cole, DVM[b,*]

KEYWORDS

• MRI • Diffusion-weighted imaging • Magnetic resonance spectrography
• Diffusion tensor imaging • Parallel imaging • CSF flow tracking

KEY POINTS

- Magnetic resonance (MR) is an exciting and ever-expanding imaging modality.
- Advances in MR technology include higher field strengths, new techniques, faster gradients, improved coil technology, and more robust sequence protocols.
- Techniques to move beyond simply generating anatomic images to studying patterns of diffusion, white matter tracking, proton spectrography, and spin labeling for flow tracking are advancing rapidly and are now feasible not only for research but also for clinical use.

INTRODUCTION

This article focuses on advanced modern MRI techniques and sequences. These topics include diffusion-weighted imaging (DWI), magnetic resonance spectroscopy (MRS), diffusion tensor imaging (DTI), and cerebrospinal fluid (CSF) tracking.

MRI is an imaging modality based on the principles of resonance of atomic nuclei (nuclear magnetic resonance).[1–3] Briefly, a magnetic resonance (MR) system is a combination of magnets, coils, gradients, and a computer control station. Using this equipment, a proton (typically hydrogen) can be excited, spatially located, and an image generated.[1,2,4] Most pathologic processes alter the environment of hydrogen protons in tissues, making MR a sensitive tool for imaging disease. When the patient is placed into the MR scanner, the hydrogen protons align with the main magnetic field (B0). An excitatory radiofrequency (RF) pulse is applied, which causes the hydrogen protons to absorb that energy, changing their energy state. When the protons return to their original energy state, a RF energy is produced and released, creating a signal detected in the receiver coil. This signal fades over time as the result of 2 processes, known as T1 and T2 relaxation. The differences in the relaxation times of tissues result in the image contrast. Water has long relaxation times, soft tissues are intermediate, and fat has short relaxation times. By using different MR sequences, these properties can be exploited and tissues differentiated.[1–4]

Disclosure: The authors have nothing to disclose.
[a] Department of Small Animal Clinical Science, University of Tennessee, 2407 River Drive, Knoxville, TN 37991, USA; [b] Department of Small Animal Clinical Science, University of Auburn, 1200 Wire Road, Auburn, AL 36839, USA
* Corresponding author.
E-mail address: rcc0025@auburn.edu

Vet Clin Small Anim ■ (2017) ■–■
http://dx.doi.org/10.1016/j.cvsm.2017.08.002 **vetsmall.theclinics.com**

Low Versus High Field

At the core of all MR systems is the magnet. The magnet determines signal to noise ratio (SNR) and therefore image quality. The SNR increases approximately linearly with field strength if a similar sequence setup is used.

MR systems are classified as open or closed and as high or low field. High-field MR is usually reserved for systems between 1.5 and 3 T.[3] Most of these systems are closed with a tunnel-like orientation. Low-field scanners are open design and range from 0.2 to 0.3 T. These systems have open sides. The benefits of low-field MR include design and cost as well as easier positioning and monitoring of the patient. Purchase cost is typically much less compared with high-field systems. High field has many advantages that make the cost differential less significant, including greater SNR resulting in improved image quality, thinner slice acquisition, and faster scan times.[3–5]

Ultrahigh Field

Ultrahigh-field MRI operates at a field strength of 7 T and up to 11.4 T. SNR and contrast are the two major contributors to the quality of the MR image, and increase with field strength.[6,7] Higher field means higher potential for lesion localization and characterization. Ultrahigh-field MRI allows the acquisition of higher resolution images with reasonable acquisition times (**Figs. 1** and **2**).[8–15]

ADVANCED TECHNIQUES

Diffusion-Weighted Imaging

DWI is a valuable tool in neuroimaging. Diffusion-weighted imaging and the apparent diffusion coefficient (ADC; calculated from the DWI) provide a quantitative measurement of the brownian motion of water in a three-dimensional space.[2,16–20] Quantification of water diffusion is obtained through the addition of strong gradient pulses that phase encode the location of the hydrogen atoms. An initial diffusion gradient pulse is applied, followed by a second opposing diffusion gradient pulse of equal strength and duration. If the water molecules are stationary, the second diffusion gradient restores the original phase of the hydrogen atoms leading to a coherent signal. If the water molecules are mobile, the phase of the protons following the second gradient will have changed, leading to a decrease in signal. DWI is performed by applying diffusion gradients to T2-weighted sequences and can be performed with a variable parameter called the b value. ADC values are calculated based on the DWI data obtained with at least 2 different b values (diffusion gradient factor). These values represent a

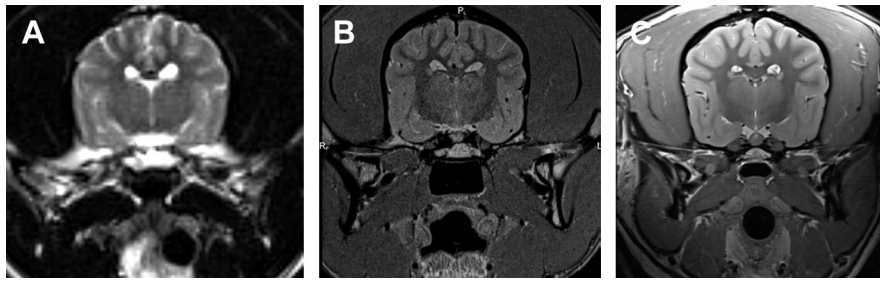

Fig. 1. Transverse T2-weighted images of a mature canine brain at the level of the thalamus. (*A*) 1.5-T turbo spin echo (TSE) T2 at 5-mm slice thickness, (*B*) 3-T TSE T2 at 0.7-mm slice thickness, and (*C*) 7-T TSE T2 0.4-mm slice thickness.