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Clinical advantages of 3.0 T MRI over 1.5 T

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Abstract

Since approval by the FDA in 2000, human MR imaging (MRI) at 3.0 T has been increasingly used in clinical practice. In spite of the potential technical challenges, a number of clinical advantages of 3.0 T MRI over 1.5 T have been identified in the recent years. This article reviews the benefits and the current knowledge of 3.0 T whole-body MRI from an evidence-based perspective and summarizes its clinical applications.

Keywords: 3 T; 1.5 T; Comparative studies; Added value

1. Introduction

High-field magnetic resonance imaging (MRI) at 3.0 T has rapidly gained acceptance in the MR community for both research and clinical applications in the last few years. The broad acceptance was supported by the advent of compact actively shielded magnets, multiple receiver coil arrays and parallel imaging capabilities as well as by research data showing improved imaging at 3.0 T in many applications. While superiority of 3.0 T MRI over 1.5 T was primarily shown in neuroradiology, ongoing research demonstrates that numerous advantages of 3.0 T over 1.5 T are also evident in body MRI.

The most straightforward advantage of high-field MRI at 3.0 T is the increased signal-to-noise ratio (SNR) that scales linearly with the field-strength (B_0). Increased SNR can be invested into decreased acquisition time, increased spatial resolution or a combination of both. Since the introduction of 3.0 T MR systems to clinical human imaging, several difficulties have been described beyond a simple SNR gain including increased energy deposition (as denoted by the specific absorption rate (SAR)), increased magnetic susceptibility effects, increased radiofrequency (RF) field inhomogeneity and more pronounced magnetic shielding effects. In the mean time, many investigators have proposed strategies to optimize imaging protocols and to decrease SAR levels and to reduce artefacts including optimized coil and hardware design, combination with parallel imaging and modulation of refocusing flip angles (see also Chapter X). With these imaging strategies several advantages of 3.0 T MRI have been identified as compared to standard imaging at 1.5 T for virtually all clinical applications.

In daily clinical practice, quality assessment is becoming more and more important to assist practitioners by providing appropriate data and recommendations for evidence-based medicine. Evidence-based practice brings pertinent information to the medical community and transfers research findings into clinical management. Levels of evidence include expert opinion and non-analytic studies (lowest level), case–control and cohort studies and systematic reviews and metaanalyses (highest level) [1].

This article addresses the current level of evidence regarding the superiority of 3.0 T MRI over 1.5 T from a clinical perspective.

2. Clinical applications

2.1. Neuroimaging

The brain and the central nervous system (CNS) are by far the most commonly investigated areas in 3.0 T MRI. As of 1 August 2007, the Pubmed search using the keywords 3.0 T and CNS/brain results in >900 hits including 26 review articles. Moving from 1.5 T or below to 3.0 T holds several promises for neurological imaging. The theoretical twofold increase in signal-to-noise ratio (SNR) can be used to either increase spatial resolution or to reduce acquisition time. However, drawbacks of 3.0 T include increased susceptibility-induced geometric

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distortion, more pronounced flow and motion artefacts and the increased deposition of RF energy. These difficulties are fortunately limited for the brain relative to other areas of the body due to the limited field-of-view (FOV) and the relatively small amount of motion.

The most straightforward use of the increased SNR in neuroimaging is for reduced signal averaging (i.e. shorter acquisition time), smaller pixel sizes (improved spatial resolution) and thinner slices or a combination of it. Tschampa et al. reported that the number of averages can be reduced by a factor of 2 in T2-weighted TSE of the hippocampus and the imaging matrix can be doubled from 512 to 1024 at 3.0 T as compared to 1.5 T while maintaining high SNR facilitating the diagnosis of hippocampal sclerosis [2].

2.2. Multiple sclerosis

The SNR increase at 3.0 T could theoretically be utilized to improve lesion detection in inflammatory cerebral disease, e.g. multiple sclerosis (MS). Bachmann et al. investigated 22 patients with MS both on a 1.5 and a 3.0 T system with FLAIR using the same spatial resolution. Bachmann et al. found that significantly more lesions were seen on the 3.0 T images and lesion conspicuity was scored to be better at 3.0 T [3]. Wattjes et al. performed a prospective intraindividual comparison between 1.5 and 3.0 T brain imaging in 40 patients with clinically isolated syndromes suggestive of MS. He reported a significantly higher sensitivity in the detection of inflammatory lesion at 3.0 T as compared to 1.5 T [4]. Translating these results to the clinically relevant McDonald classification in a subgroup of 19 patients, Wattjes et al. found that one patient turned from McDonald negative to McDonald positive [5]. Clinically, the classification according to the 3.0 T MRI means for the individual patient a much higher probability of developing definite MS than it was suspected at 1.5 T MRI. The advantage of 3.0 T over 1.5 T in patients with clinically isolated syndromes may be the diagnosis of more subtle changes in the white matter (Fig. 1) and the better prediction of the development of definite MS as well as the course of the disease. Potential implications of evidence-based findings might be the early treatment and the beginning of rehabilitation. Of high clinical relevance is already today the difference in the clinical score according to the field strength: in average, patients in the comparative study by Wattjes were scored one Barkhof score higher on 3.0 T MRI as compared to the corresponding 1.5 T MRI [4]. In a study of 25 patients with MS, Sicotte et al. reported a 21% increase in the number of detected contrast-enhancing lesions, a 30% increase in enhancing lesion volume and a 10% increase in total lesion volume on 3.0 T imaging relative to 1.5 T imaging, respectively [6]. Furthers multi-center studies are needed and underway to confirm these initial findings and to investigate the role of 3.0 T MR imaging in MS with respect to its implication for therapy, outcome and disability. Recent studies suggest already that 3.0 T may have an impact on the MS classification and the currently used scores might have to be revised [5].

2.3. Brain tumors

A stronger effect of Gadolinium-based contrast agents is noticed on T1-weighted MR imaging, at 3.0 T. While the relaxivity of Gadolinium-chelates is almost constant between 1.5 and 3.0 T, the enhancement (i.e. post-contrast versus pre-contrast signal) is increased at 3.0 T due to the T1 prolongation of tissue. This can be explained by the fact that a stronger effect of T1-shortening contrast agents is perceived with longer baseline T1-relaxation times. Krautmacher et al. reported from an intraindividual comparative trial of patients with contrast-enhancing brain lesions that a higher lesion-to-brain contrast was seen at high field MR compared to 1.5 T even with half of the standard dose [7]. In dynamic susceptibility contrast (DSC) perfusion imaging of the brain at 3.0 T, Manka et al. reduced the total dose of contrast material to one fourth of the standard dose at 1.5 and still maintained the diagnostic quality yielding values of mean transit time (MTT) that did not significantly differ between full standard (0.2 mmol/kg bw), half standard (0.1 mmol/kg bw) and quarter of standard (0.05 mmol/kg bw) doses [8]. In a recent systematic study of rat gliomas by Wintersberger et al., the SNR gain in TSE sequence at 3.0 T came close to the theoretically expected doubling with an even higher tumor contrast-to-noise ration (CNR) increase [9]. However, tumor CNR gain was lim-

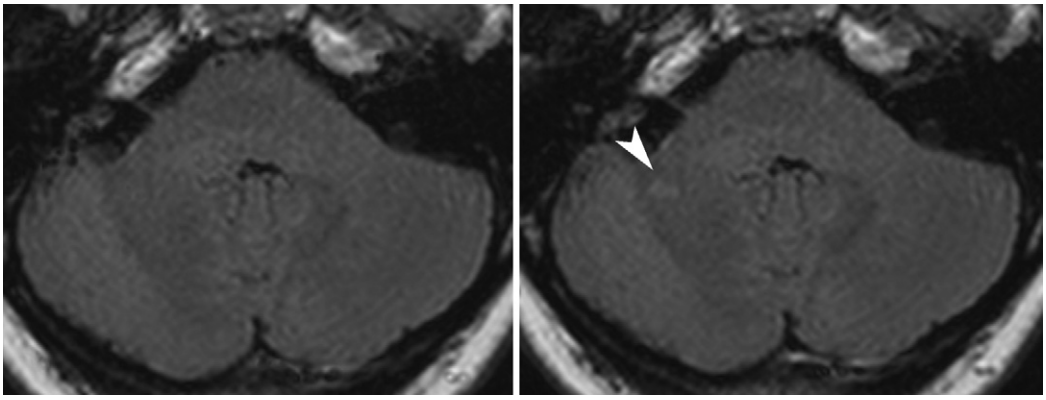

Fig. 1. Intraindividual comparison of axial T2-wheighted FLAIR image in a 31-year-old female patient presenting with unilateral optic neuritis. Higher sensitivity in the detection of an inflammatory brain lesion is documented at 3.0 T (image on the right) as compared to 1.5 T (image on the left) with a lesion detected on the 3.0 T but not on the 1.5 T image (arrow head).