High-resolution T₂-reversed magnetic resonance imaging on a high-magnetic field system

Technical note

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Because of the high signal-to-noise (S/N) ratio, T₂-weighted images obtained using high-field magnetic resonance (MR) imaging systems can be expected to provide high anatomical and contrast resolution. Furthermore, the improved structural and contrast resolution of these high S/N T₂-weighted images can be processed for optimum perceptual resolution through the application of gray-scale reversal and expansion of the gray-scale window, known as T₂-reversed (T2R) imaging. In this study, the authors investigated high-resolution T2R MR imaging performed on a high-field (3-tesla) system for its clinical utility in detecting various physiological and pathological conditions.

Key Words * magnetic resonance imaging * high magnetic field * high-resolution imaging * brain * T₂ weighting

High-field (3 teslas or greater) magnetic resonance (MR) imaging systems developed for research purposes in recent years have contributed significantly to the field of functional MR imaging and multinuclear spectroscopy.[1-3,6,7] As more experience is gained, it has become apparent that high-field systems possess significant advantages over conventional MR imaging systems in the clinical setting as well, primarily because of the high signal-to-noise (S/N) ratio.[8]

The main goal of clinical imaging is the detection of pathological lesions in detailed anatomical resolution within a target structure. Standard clinical MR imaging studies are most commonly used to provide T₁-weighted, T₂-weighted, and proton density-weighted images, and, depending on the clinical situation, intravenous contrast-enhanced T₁-weighted images. Other methods developed to increase detection sensitivity for specific pathological processes, such as diffusion-weighted images[5] and fluid-attenuated inversion recovery[4] are becoming increasingly popular. However, the implicit goal in the standard clinical application of any MR imaging method is maximum yield of clinical information at the lowest cost, whether that is measured in patient comfort, money, or professional interpretation, all of which are principally determined by the length of imaging time and the number of images generated. The large number of possible combinations of differential sequences are obviously not practical or cost effective from a clinical perspective. Therefore, an imaging method that could provide the information necessary for clinical diagnosis in a single study would be efficient and convenient.

Among the various available contrast mechanics, T₂ is sensitive in detecting most pathological

alterations in the central nervous system. Because T_2 contrast has an intrinsically lower S/N ratio than T_1 , it yields a lower anatomical resolution. Using high-field systems, this disadvantage can be effectively eliminated. High-field T_2 -weighted imaging, therefore, may potentially provide the combination of good anatomical and contrast resolution in a single study. Furthermore, certain image presentation techniques can be used to improve perceptual resolution. In the case of T_2 -weighted contrast images, reversal of the gray scale may improve physiological resolution and expansion of the gray scale window may provide finer contrast resolution. At conventional field strengths, however, such image manipulation offers little benefit because of an insufficient S/N ratio. If, on the other hand, T_2 -weighting offers a high S/N ratio and good contrast, improved image presentation could be achieved. In this study, we investigated the utility of such a technique, high-field T_2 -reversed (T2R) imaging, in the evaluation of normal and diseased central nervous systems.

CLINICAL MATERIAL AND METHODS

A research imaging system (Signa; GE Medical Systems, Waukesha, WI) with a superconductive magnet operated at 3 teslas (Magnex, Abingdon, Oxon, UK) was used to perform all the imaging studies. Informed consent was obtained from all participants. Images were obtained in normal volunteers and patients according to the human research guidelines of the Internal Review Board of the University of Niigata.

Data were obtained using a fast spin-echo (FSE) sequence with the following parameters: TR 4000 msec; TE 17 msec; 8 acquisitions; 12 X 12 cm field of view; matrix size 512 X 512; and 12-echo train. Considering the specific absorption rate, the number of slices obtained in a single FSE session was limited to five (slice thickness, 5 mm, interslice gap 2.5 mm). Raw data were obtained using 256 phase-encoding steps (number of experiments = eight) and were then zero-filled into 512 datapoints. The total scanning time necessary to obtain five slice images was 12 minutes. After conventional two-dimensional Fourier transformation, the gray scale of the images was inverted and given an expanded window range.

Fig. 1. Left: Coronal MR image of normal brain in a 39-year-old woman, showing detailed structures of the vertebrobasilar artery system. Note clear visualization of small pontine vessels and oculomotor nerves. Right: Coronal MR image of normal brain (a 28-year-old man) at the level of Meckel's cave. Note the exquisite anatomical detail, showing the motor portion of the trigeminal nerve (magnified view at lower right).

RESULTS

The T2R MR images were found to be especially useful for elucidating extraaxial structures. (Fig. 1). Unprecedentedly clear definition of anatomical structures can be readily obtained. For example, the normal gasserian ganglion of the trigeminal nerve within the petrosal bone is visualized with remarkable clarity. Each component of the gasserian ganglion (V1, V2, V3, and motor) is resolved independently (Fig. 1 right). The significance of high-resolution T2R MR images as a powerful clinical imaging tool is evident from the images representing a variety of pathological processes (Figs. 2 and 3). This imaging technique is also an excellent means for elucidating the fine details of intraaxial pathology (Fig. 4).

Fig. 2. Upper: Axial MR image of the brain of a 24-year-old woman, showing a large arteriovenous malformation in the right occipital lobe. Lower Left: Coronal MR image of

the interpeduncular cistern in a 73-year-old woman with an aneurysm at the top of the basilar artery. Note the clearly defined relationship between the aneurysm and its surroundings. Lower Right: Coronal MR image of the basal cistern in a 28-year-old woman with moyamoya disease. Note the clear visualization of fine moyamoya vessels in the cistern.

Fig. 3. Upper: Axial MR image of the pontomedullary junction in a 62-year-old woman with right-sided hemifacial spasm. Compression of the right facial nerve by a loop of the right anterior inferior cerebellar artery at the entry zone of the nerve root is clearly seen. Lower Left: Axial MR image of the auditory canals in a 55-year-old woman with a small tumor in the left internal auditory canal. Note that clear identification of the tumor is readily obtained without administration of intravenous contrast medium. Lower Right: Coronal MR image of Meckel's cave in a 50-year-old woman with a trigeminal neurinoma.

DISCUSSION

Magnetic resonance imaging undoubtedly represents a significant advancement in clinical imaging. Its ability to provide structural and functional information has made it an indispensable clinical tool. However, paradoxically, the versatility of MR imaging poses a disadvantage as well. The theoretically unlimited number of choices in contrast mechanics often precludes simple standardization in the clinical

setting. In principle, successful clinical application of any new MR imaging method is governed by patient comfort and economic feasibility, which are primarily determined by the length of time required to complete a study.

Fig. 4. Left: Axial MR image of the pons of an 18-year-old woman with a cavernous hemangioma. Hemosiderin deposits are clearly visualized as a low-intensity (white) area. Right: Axial MR image of the frontal lobe of a 21-year-old man with glioma.

One of the obvious advantages of high-field imaging is the high S/N ratio as compared with conventional MR imaging systems. Relaxation properties of tissue water protons are known to be field dependent. On high-field systems, conventional FSE sequences produce images that are more heavily T_2 contrast weighted.[1-3, 6-8] High-field imaging, therefore, allows for distinct improvement in the spatial quality of T_2 -weighted MR images. Based on physiological resolution, reversing the gray scale of high S/N ratio T_2 -weighted images often improves perceptual structural resolution (Fig. 5). Additionally, expansion of the gray scale window allows for finer contrast representation.

Fig. 5. A representative T₂-weighted image (lower) and its T2R counterpart (upper) demonstrating that differences in display alter physiological resolution and, hence, the detection sensitivity.

Our studies of normal volunteers and patients presenting with a variety of neuropathological conditions demonstrated the utility of high-field T2R MR imaging. A clear advantage over conventional MR imaging is its ability to provide exquisite anatomical resolution, while at the same time increasing the detection sensitivity of pathological processes. High-field T2R imaging appears to have promise as the next generation MR imaging technique in the clinical setting.

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