Brain and Spinal Cord MR Imaging Features in Multiple Sclerosis and Variants

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KEYWORDS

• Multiple sclerosis • MR imaging • Protocol • Diagnostic criteria • Differential diagnosis

KEY POINTS

- Multiple sclerosis pathology has certain imaging characteristics that have been incorporated into diagnostic criteria.
- Focal multiple sclerosis lesions are ovoid shaped, perivascularly located, have specific locations throughout the central nervous system, and are not restricted to the white matter.
- MR imaging plays a crucial role in diagnosing multiple sclerosis, in predicting the prognosis, and monitoring of the disease course (treatment efficacy and safety).
- Standardized imaging acquisition, reading, and reporting according to recent expert panel guidelines is highly recommended.
- Diagnostic criteria are crucial for the correct diagnosis of multiple sclerosis.

INTRODUCTION

Multiple sclerosis (MS) is the most frequent chronic, inflammatory, demyelinating disease of the central nervous system in young adults leading to long-term disability.[1] In addition to the clinical presentation, including the neurologic examination and cerebrospinal fluid (CSF) markers (eg, the demonstration of oligoclonal bands), MR imaging of the brain and spinal cord plays a crucial role for diagnostic and disease-monitoring purposes.[2] In 2001, for the first time, brain and spinal cord MR imaging have been incorporated into the MS diagnostic criteria (McDonald criteria) for the demonstration of both dissemination in space (DIS) and in time (DIT).[3] The 2005 and the 2010 revisions of the McDonald criteria have further reinforced the crucial role of MR imaging in the diagnosis of MS, allowing the diagnosis of MS in patients with clinically isolated syndrome (CIS) with only 1 MR imaging scan.[4,5] Although MS pathology has some characteristic imaging characteristics and follows a certain distribution pattern, other pathologies (eg, vascular, inflammatory) can mimic MS pathology clinically as well as radiologically, leading to a broad spectrum of differential diagnoses. MR imaging, in particular spinal cord imaging, can aid in making the correct diagnosis, and exclude relevant differential diagnoses.[6,7] Unfortunately, MR imaging pathology does not correlate well with the clinical presentation and disease progression with respect to clinical outcome measures such as physical disability and cognitive performance, which has

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coined the term "clinico-radiological paradox" in MS.[8,9] This is probably because MS pathology on MR imaging is heterogeneous with respect to pathology distribution involving gray and white matter structures of the brain and spinal cord to different degrees. In addition to focal pathology, diffuse white and gray matter changes (diffusively abnormal white matter [DAWM] and gray matter [DAGM]), as well as pathology that is not visible on conventional MR imaging (normal-appearing gray and white matter), contribute substantially to the clinical presentation and the functional outcome.[10–14]

In addition to the MS diagnosis and differential diagnosis, there is increasing and conclusive evidence that MR imaging is also useful for prognostic classification and for monitoring the disease progression, treatment efficacy, and safety.[15]

The aim of this review was to give a comprehensive overview of brain and spinal cord imaging in MS with special regard to different MR imaging approaches for diagnosing MS and distinguishing MS variants.

IMAGING OF MULTIPLE SCLEROSIS, MR IMAGING PROTOCOLS OF BRAIN, SPINAL CORD, AND TREATMENT MONITORING

Because imaging has become increasingly important for the diagnosis and monitoring of MS, there is an unmet medical need for the standardization of the MR imaging acquisition, timing of MR imaging scanning, and image interpretation/reporting.[5] The need for standardization goes beyond the diagnostic process and is of special clinical relevance for those patients with an established diagnosis of MS and being treated with MS therapeutics. In 2015, evidence-based guidelines were published by the Magnetic Resonance Imaging in MS (MAGNIMS) study group (www.magnims.eu) and the Consortium of MS Centers (CMSC), creating a framework for clinical MR imaging sequences necessary for the diagnostic and monitoring processes.[15,16]

MR Imaging Protocol of the Brain

Table 1 shows the recommended MR imaging acquisition protocol, including mandatory and optional brain MR imaging sequences for baseline assessment and follow-up examination as proposed by the MAGNIMS and the CMSC panel. Due to the higher detection of white and gray matter MS lesions in the brain, the use of an MR imaging system operating at 3 T is recommended, applying standard spatial resolution parameters (slice thickness of 3 mm, in-plane resolution of 1 × 1 mm) for diagnostic and monitoring purposes.[17–20]

Mandatory sequences in the MR imaging protocols for diagnosing, disease monitoring, and treatment include T2-weighted imaging, T2-fluid-attenuated inversion recovery (T2-FLAIR), and T1-weighted imaging, including contrast

Table 1
Protocols for brain MR imaging acquisition for diagnostic purposes

MR Imaging sequences	Baseline MR Imaging MAGNIMS	Baseline MR Imaging CMSC	Follow-up MR Imaging MAGNIMS
Axial PD and/or T2-FLAIR/T2-weighted	Yes	Yes, 3D	Highly recommended
Sagittal 2D or 3D T2-FLAIR	Yes	Yes[b]	Optional
2D or 3D contrast-enhanced T1-weighted[a]	Yes	Yes,[b] precontrast and postcontrast	Yes
Unenhanced 2D or high-resolution isotropic 3D T1-weighted	Optional	Yes[b]	Optional
2D and/or 3D DIR	Optional	No	Optional
Axial diffusion-weighted imaging	Optional	Yes	No

Abbreviations: CMSC, Consortium of MS Centers; DIR, double inversion recovery; FLAIR, fluid-attenuated inversion recovery; MAGNIMS, Magnetic Resonance Imaging in MS; PD, proton density; 2D, 2 dimensional; 3D, 3 dimensional.

[a] Standard contrast administration: single dose, 0.1 mmol/kg body weight.

[b] Three-dimensional acquisition precontrast and postcontrast.

Adapted from Traboulsee A, Simon JH, Stone L, et al. Revised recommendations of the Consortium of MS Centers task force for a standardized MRI protocol and clinical guidelines for the diagnosis and follow-up of multiple sclerosis. AJNR Am J Neuroradiol 2016;37(3):394–401; and Rovira A, Wattjes MP, Tintore M, et al. Evidence-based guidelines: MAGNIMS consensus guidelines on the use of MRI in multiple sclerosis-clinical implementation in the diagnostic process. Nat Rev Neurol 2015;11(8):471–82.