



Recommendations of the Polish Medical Society of Radiology and the Polish Society of Neurology for a protocol concerning routinely used magnetic resonance imaging in patients with multiple sclerosis

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ABSTRACT

Magnetic resonance imaging (MRI) is a widely used method for the diagnosis of multiple sclerosis that is essential for the detection and follow-up of the disease.

Objective. The Polish Medical Society of Radiology (PLTR) and the Polish Society of Neurology (PTN) present the second version of their recommendations for investigations routinely conducted in magnetic resonance imaging departments in patients with multiple sclerosis. This version includes new data and practical comments for electroradiology technologists and radiologists. The recommended protocol aims to improve the MRI procedure and, most importantly, to standardise the method of conducting scans in all MRI departments. This is crucial for the initial diagnostics necessary for establishing a diagnosis, as well as for MS patient monitoring, which directly translates into significant clinical decisions.

Introduction. Multiple sclerosis (MS) is a chronic immune mediated inflammatory demyelinating disease of the central nervous system (CNS), the aetiology of which is still unknown. The nature of the disease lies in a CNS destruction process disseminated in time (DIT) and space (DIS). MRI detects focal lesions in the white and grey matter with high sensitivity (although with significantly lower specificity in the latter). It is also the best tool to assess brain atrophy in patients with MS in terms of grey matter volume (GMV) and white matter volume (WMV) as well as local atrophy (by measuring the volume of thalamus, corpus callosum, subcortical nuclei, and hippocampus) as parameters that correlate with disability progression and cognitive dysfunctions. Progress in MR techniques, as well as advances in postprocessing the obtained data, has driven the dynamic development of computer programs that allow for a more repeatable assessment of brain atrophy in both cross-sectional and longitudinal studies.

MR imaging is unquestionably the best diagnostic tool available to follow up the course of the disease and support clinicians in choosing the most appropriate treatment strategy for their MS patient. However, to diagnose and follow up MS patients on the basis of MRI in accordance with the latest standards, the MRI study must adhere to certain quality criteria. Such criteria are the subject of this paper.

Key words: multiple sclerosis, magnetic resonance imaging, imaging protocol, guidelines

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Recommendations for MRI in MS patients on MRI scanners with field strength at least 1.5T

General comments

Patients with MS are recommended to undergo MRI with an intravenous administration of a paramagnetic contrast medium (gadolinium) solely as a part of initial diagnostics.

A follow-up gadolinium-enhanced MRI with the use of macrocyclic contrast agents is recommended only in cases of a clinical progression of the disease, or if the need arises for another differential diagnosis of MS, or in another clinically justified situation. The retention characteristics of each gadolinium-based contrast agent (GBCA) should be considered in all patients; linear GBCAs have been shown to result in greater retention, and retention for longer, than macrocyclic GBCAs. This is why the use of linear contrast agents based on gadolinium (GBCA) is not recommended in following up the treatment of MS in clinically and radiologically stable patients, due to the potential occurrence of long-term side effects associated with the accumulation of contrast agent within the CNS.

Patients with clinically isolated syndrome (CIS) or suspected MS should undergo:

- Head MRI before and after an intravenous administration of a contrast agent (Tab. 1).
 - It is recommended that an additional scan of the cervical and thoracic sections of the spinal cord (in accordance with the referral/indication of the neurologist) is performed after an intravenous administration of a contrast agent, especially when head MRI does not meet the diagnostic criteria or when clinical symptoms suggest the lesions are located in the spinal cord (Tab. 2). Ideally, MRI studies of the head and the cervical/thoracic spine should be performed within a single MRI imaging session.
- MRI of the spinal cord is particularly important in the diagnosis of primary progressive MS according to the current disease diagnosis criteria (Tab. 3).
- In patients with multifocal damage to the nervous system involving symptomatology associated with both brain and spinal cord impairment, in order to shorten the diagnostic time, (and according to the referring neurologist's recommendations) it is possible to perform simultaneously an MRI of the head and of a selected section of the spinal cord using a combined protocol (Tab. 4).
- Recommendations for disease progression follow-up based on MRI:
- Head MRI to show new/enlarging demyelinating lesions (Tab. 1) at least every 12 months during the initial years

Table 1. Head MRI protocol

Parameters	Description
Electromagnetic field	Images should be of good quality with an appropriate SNR value and resolution ($\leq 1 \times 1$ mm)
Reference setting	When setting the scanning plane, use a line parallel to the lower edges of the rostrum and splenium of the corpus callosum; also have an identical angulation of the planned slices to that of the slices in the previous study (Fig. 1)
Scanning range	Whole brain scanned
Slice thickness and gaps	≤ 3 mm, with no gaps (for 2D and 3D acquisition)
Basic sequences	<ol style="list-style-type: none"> 3DT1 axial isotropically T2 axial DWI axial (with ADC map) Administration of a contrast medium ¹ (T1 sequence 5–10 minutes after administration) <ol style="list-style-type: none"> FLAIR+C sagittal FLAIR+C axial 3DT1+C axial isotropically²
	¹ The recommended dose of a contrast medium is 0.1 mmol/kg body mass; see General Comments.
	² It is recommended to perform and record sagittal reconstructions and archive them on a CD (and in the PACS system if available), as an integral part of the examination
Optional sequences	<ol style="list-style-type: none"> PD SWI – to identify central veins in lesions and microbleedings DIR – to evaluate cortical and subcortical foci

SNR — signal-to-noise ratio; 2D — two-dimensional; 3D — three-dimensional; DWI — diffusion-weighted imaging; ADC — apparent diffusion coefficient; FLAIR — fluid-attenuated inversion recovery sequence; +C — postcontrast; PD — proton density; SWI — susceptibility weighted imaging; DIR — double inversion recovery; PACS — picture archiving and communication system

Table 2. Spinal cord section MRI protocol

Parameters	Description
Electromagnetic field	Images should be of good quality with an appropriate SNR value and resolution ($\leq 1 \times 1$ mm)
Scanning range	Spinal cord section scanned
Slice thickness and gaps	Sagittal: ≤ 3 mm, no gaps (for 2D and 3D) Axial: 3 mm, no gaps
Basic sequences	<ol style="list-style-type: none"> T2 sagittal T1 sagittal Administration of a contrast medium ¹ (T1 sequence 5–10 minutes after administration) <ol style="list-style-type: none"> STIR/T2 FAT-SAT, PD or PST1-IR+C sagittal T2+C axial at the level of the lesions visible in sagittal sequences T1+C sagittal T1+C axial
	¹ The recommended dose of a contrast medium is 0.1 mmol/kg body mass; see General Comments
Optional sequences	<ol style="list-style-type: none"> T2 coronal at the level of the lesions visible in the other sequences 3DT1 sagittal (to assess spinal cord atrophy)

SNR — signal-to-noise ratio; 2D — two-dimensional; 3D — three-dimensional; STIR — short tau inversion recovery; FAT-SAT — fat saturation; PD — proton density; PST1-IR — phase-sensitive T1-weighted inversion-recovery; +C — postcontrast

of treatment, but possibly less frequently later in patients with complete clinical stability.

- Cervical and/or thoracic spinal cord scan is recommended, according to the neurologist's referral/indication.

For patients under the age of 18, the MRI protocol for brain and spinal cord examination remains unchanged; examination is the same as in the adult population.

Brain MRI protocol for MS patients

In order to use the same scanning planes during the follow-up examinations, it is recommended to achieve slices in the true midline plane.

For this purpose, once three localisation slices have been performed, five slices with a thickness of 3 mm should be

Table 3. 2017 McDonald criteria for MS diagnosis

Clinical presentation	Additional criteria required for diagnosis
Minimum two relapses, clinical signs from two foci	Not required*
Minimum two relapses, clinical signs from one focus	DIS damage to the nervous system on MRI or another relapse of different clinical location
One relapse, clinical signs from two or more foci	DIT damage to the nervous system on MRI, or presence of specific oligoclonal bands in cerebrospinal fluid (absent in serum) or subsequent relapse
One relapse, clinical signs from one focus (isolated CNS damage)	DIS and DIT damage to the nervous system on MRI, or presence of specific oligoclonal bands (absent in serum) in cerebrospinal fluid
Primary progressive MS	One year of neurological disability progression diagnosed prospectively or retrospectively, and two of the following conditions fulfilled: <ol style="list-style-type: none"> 1. MRI dissemination in space (but one and not two typical locations required) 2. MRI dissemination in space in the spinal cord (minimum of two lesions) 3. Positive CSF test (presence of oligoclonal bands, absent in serum, and/or elevated immunoglobulin index)

*Once other possible causes of symptoms have been excluded; in practice, every patient with suspected MS should undergo as a minimum an MRI of the head and spinal cord as well as a lumbar puncture

Table 4. Head and spinal cord section MRI protocol (combined)

Parameters	Description
Electromagnetic field	Images should be of good quality with an appropriate SNR value and resolution ($\leq 1 \times 1$ mm)
Scanning range	Brain and spinal cord scanned
Slice thickness and gaps	Head and spinal cord (sagittal) ≤ 3 mm, no gaps (for 2D and 3D) Spinal cord (axial): 3 mm, no gaps
Basic sequences	<ol style="list-style-type: none"> 1. Use protocol prior to the administration of a contrast medium for the head Administration of a contrast medium¹ (T1 sequence 5–10 minutes after administration) 2. FLAIR+C sagittal (head) 3. FLAIR+C axial (head) 4. 3DT1+C axial isotropically (head)² 5. T2+C sagittal (spinal cord section) 6. STIR/T2 FAT-SAT, PD or PST1-IR+C sagittal (spinal cord section) 7. T2+C axial at the level of the lesions visible in sagittal sequences (spinal cord section) 8. T1+C sagittal (spinal cord section) 9. T1+C axial (spinal cord section) <p>¹The recommended dose of a contrast medium is 0.1 mmol/kg body mass; see General Comments.</p> <p>²It is recommended to perform and record sagittal reconstructions and archive on a CD (and in the PACS system if available), as an integral part of the examination</p>
Optional sequences	As in the specified protocols of the head and spinal cord

SNR — signal-to-noise ratio; 2D — two-dimensional; 3D — three-dimensional; FLAIR — fluid-attenuated inversion recovery sequence; STIR — short tau inversion recovery; FAT-SAT — fat saturation; PD — proton density; PST1-IR — phase-sensitive T1-weighted inversion-recovery; +C — postcontrast; PACS — picture archiving and communication system

planned as accurately as possible in the sagittal plane on T2-weighted images.

The planned slices should be set parallel to the longitudinal cerebral fissure using the localisation slices, in the transverse and frontal planes. The third of these five slices should pass through the median fissure as accurately as possible.

Cross-sectional slices should be set on the thereby obtained midline slice in parallel to the lower limits of the rostrum (anterior commissure, AC) and splenium of the corpus callosum

(posterior commissure, PC), according to the AC-PC reference line (Fig. 1).

Note: During the follow-up examinations, when the scanning plan is set in the reference to the corpus callosum, it is vital to compare the angulation of the planned slices with the angulation of the slices in the previous study.

Some scanners do not have the possibility of remembering a single slice; in such case the slice should be carefully defined as shown in Figure 1.

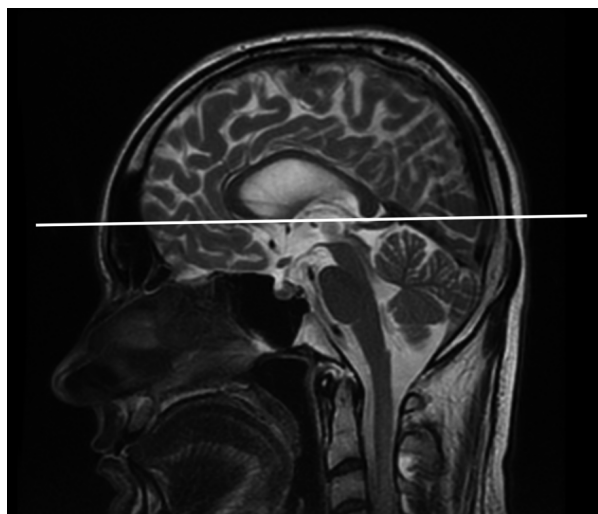


Figure 1. A pre-specified reference line parallel to the corpus callosum

Note:

1. The direction of scanning in axial scans must be upwards, whereas in sagittal scans it must be from right to left (also when scanning spinal cord).
2. Gaps between slices should be as small as possible (we propose 0.3 mm, i.e. 10% slice thickness or no gap).
3. 3DT1 — we recommend performing this sequence first, to avoid motion artifacts in the course of the examination. This sequence allows for precise volumetric evaluation of the brain.
4. Both FLAIR sequences should be performed after the administration of a contrast medium, to delay the onset of T1+C acquisition (within the range of 5–10 minutes) in order to achieve better contrast enhancement. A contrast medium does not lessen the quality of FLAIR images. At the same time, the patient’s time spent in the scanner is used optimally. The possible enhancement of cortical demyelinating lesions or leptomeninges does not affect study interpretation, because enhancement is in any case assessed on the basis of T1-weighted sequences.

5. If scanning with 3DT2 and 3DFLAIR sequences, if possible they should be done in the sagittal plane and should be used with subsequent cross-reconstruction with 3 mm slices in the plane set up to the lower edge of the corpus callosum. When scanning in this way, clinicians should consider conducting the 3DT2 sequence scan after a contrast medium injection, so as to ensure an appropriate delay in T1 acquisition.
6. If software which automatically determines the angulation/range of the layers can be used, as in the previous examination, such a function is recommended.

A radiological report should include standard terminology used in brain assessment.

Description of focal lesions:

1. Location (supratentorial region: cortical, juxtacortical, central white matter, periventricular, infratentorial, corpus callosum, brainstem, spinal cord).
2. Size — the range of the longest dimension provided i.e. from–to. In the case of multiple lesions, report the size of the largest lesion only (in mm). According to the current definition, demyelinating lesions are defined as lesions of ≥ 3 mm in diameter.
3. The number of demyelinating lesions – specify according to the following scheme: 1, 2, 3–8, ≥ 9 .
4. The nature of the lesion, i.e. specify whether the appearance is typical for MS demyelination, or whether differential diagnosis is required, e.g. ischaemic lesion.
5. Whether the lesions are disseminated in space (DIS) and meet the 2017 McDonald criteria (Tab. 3 and Tab. 5).
6. Comparison with the previous head and spinal cord MRI (if available). In patients with suspected MS, comparison with the previous MRI to assess disease activity and eligibility for treatment. In on-treatment patients, comparison with the previous examination and baseline examination performed prior to treatment initiation.
7. Activity assessment, i.e. the number of contrast-enhancing foci in the current examination and the number of new/enlarging lesions compared to the baseline and the previous examination. Please specify according to the scheme: 1, 2, 3–8, ≥ 9 .

Table 5. DIS and DIT damage to the nervous system according to the 2017 McDonald criteria

Damage to the CNS disseminated in space (DIS)	Damage to the CNS disseminated in time (DIT)
Minimum one T2 lesion present in at least two typical locations: 1. Juxtacortical/cortical 2. Periventricular 3. Infratentorial 4. Spinal cord	Occurrence of new lesions on T2-weighted images and/or contrast-enhanced lesions on a subsequent MRI scan compared to a reference examination, regardless of the time elapsed since the baseline examination, or concomitant occurrence of contrast-enhancing and non-enhancing lesions, regardless of the time of this examination in relation to the time of the onset of neurological signs and symptoms (may also be a basic examination), or immunological equivalent of radiological dissemination over time: confirmation of the presence of specific oligoclonal bands (absent in serum) in the cerebrospinal fluid

8. Assessment of brain atrophy. We recommend avoiding expressions such as “brain atrophy” or “cerebral atrophy” in the report. If possible, provide current whole brain volume, grey matter volume, white matter volume, corpus callosum volume, and the volume of the right and left thalami.

There is a growing need for volumetry assessment in MS patient imaging, because it potentially can change treatment decisions. Many important factors influence volumetric calculations, including acquisition parameters, intrascanner variability, pseudoatrophy, and patient hydration or movement. Having appropriate 3DT1 sequences in the protocol makes it possible to use software available on the market that can measure patient atrophy over time. Volumetric applications differ in the range of output results, and cost is another very important factor. This is why volumetric analysis of the brain should be performed using certified software, and preferably by a central institution in order to standardise results.

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