Consensus Recommendations of the Multiple Sclerosis Study Group and the Portuguese Neuroradiological Society for the Use of Magnetic Resonance Imaging in Multiple Sclerosis in Clinical Practice: Part 2.


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ABSTRACT

Introduction: Magnetic resonance imaging is recognized as the most important diagnostic test in the diagnosis of multiple sclerosis, differential diagnosis and evaluation of progression/therapeutic response. However, to make optimal use of magnetic resonance imaging in multiple sclerosis, the use of a standard, reproducible and comparable imaging protocol is of uttermost importance. In this context, the Portuguese Society of Neuroradiology and the Group of Studies of Multiple Sclerosis, after a joint discussion, appointed a committee of experts to create recommendations adapted to the national reality on the use of magnetic resonance imaging in multiple sclerosis. This document represents the second part of the first Portuguese consensus recommendations on the use of magnetic resonance imaging in multiple sclerosis in clinical practice.

Material and Methods: The Portuguese Society of Neuroradiology and the Group of Studies of Multiple Sclerosis, after discussing the topic in national meetings and after a working group meeting held in Figueira da Foz, May 2017, appointed a committee of experts that have developed several standard protocols on the use of magnetic resonance imaging on multiple sclerosis by consensus. The document obtained was based on the best scientific evidence and expert opinion. Portuguese multiple sclerosis consultants and departments of neuroradiology scrutinized and reviewed the consensus paper; comments and suggestions were considered. Standardized strategies of magnetic resonance imaging referral in clinical practice for diagnosis and follow-up of multiple sclerosis were published in the first part of this paper.

Results: We provide magnetic resonance imaging acquisition protocols regarding multiple sclerosis diagnostic and monitoring and the information to be included in the report for application across Portuguese healthcare institutions.

Conclusion: We hope that these first Portuguese magnetic resonance imaging guidelines will contribute to optimize multiple sclerosis management and improve patient care in Portugal.

Keywords: Demyelinating Diseases; Magnetic Resonance Imaging; Multiple Sclerosis; Practice Guidelines as Topic

RESUMO

Introdução: A ressonância magnética é considerada o exame complementar mais importante para o diagnóstico de esclerose múltipla, seus diagnósticos diferenciais e avaliação da sua progressão/resposta terapêutica. No entanto, para um uso ótimo desta ferramenta na esclerose múltipla, é essencial a aplicação de um protocolo de imagem padronizado, reprodutível e comparável. Neste contexto, o Grupo de Estudos de Esclerose Múltipla e a Sociedade Portuguesa de Neuroradiologia, após discussão conjunta, designaram um comitê de peritos para a criação de recomendações adaptadas à realidade nacional sobre a utilização da ressonância magnética na esclerose múltipla. Este documento corresponde à segunda parte das primeiras recomendações de consenso portuguesas sobre a utilização da ressonância magnética na esclerose múltipla na prática clínica.

Material e Métodos: O Grupo de Estudos de Esclerose Múltipla e a Sociedade Portuguesa de Neuroradiologia após discussão do tema em reuniões de âmbito nacional e de uma reunião do grupo de trabalho que teve lugar na Figueira da Foz em maio de 2017, designaram um comitê de peritos que elaboraram por método de consenso protocolos padronizados sobre o uso da ressonância magnética na esclerose múltipla. O documento teve como base a melhor evidência científica e a opinião dos peritos. Posteriormente,
INTRODUCTION

Since the first formal inclusion of magnetic resonance imaging (MRI) in multiple sclerosis (MS) diagnostic criteria in 2001, we have witnessed significant imaging advances and widespread clinical implementation. MRI is presently the most important diagnostic test in the diagnosis of MS, differential diagnosis and to evaluate MS dissemination in space and/or time. MRI is a fundamental tool for monitoring therapeutic response and depicting adverse effects of treatment.

MRI accuracy in detecting MS plaques and in differentiating these from other mimickers depends on the MR protocols and specific technical parameters. This is even more critical for monitoring response to therapy and to determine progression of clinically silent disease. The use of a standard, reproducible and comparable imaging protocol with satisfactory image quality between serial studies is of utmost importance to guide the management of MS patients.

The purpose of this document, based on the professional experience and the best scientific evidence available, is to present the first Portuguese consensus recommendations of an MS MR imaging protocol, for nationwide implementation. These recommendations are aimed at making better initial diagnoses as well as reliable imaging comparisons during follow-up, in the clinical practice setting. A structured neuroimaging report for MS, using a universal language with clinical appropriateness, will also be presented.

MATERIAL AND METHODS

The Portuguese Society of Neuroradiology-forum (SPNR-forum) and the Grupo de Estudos de Esclerose Múltipla (GEEM, the main Portuguese healthcare professionals group dedicated to MS study and treatment), supported by the Portuguese Neurological Society, nominated among their respective members a group of experts, originating from academic and community-based MS centers, to convey and write the first draft of a consensus, based on the best available scientific evidence and clinical expertise.

The SPNR-forum initiated its activity in 2016 by revising the recently published scientific evidence, integrated with the clinical expertise and available advances in imaging technology, to define standardized MR protocols for diagnosis and monitoring of MS in order to implement them nationwide in imaging departments/institutions.

The SPNR-forum and the GEEM nominated a working group to develop the first Portuguese National recommendations for the use of the magnetic resonance imaging in multiple sclerosis in clinical practice. After several discussions about the topic in national meetings and after a working group meeting held in Figueira da Foz, in May 2017, a standard protocol on the use of MRI in MS was developed by consensus. The document obtained was based on the best scientific evidence and expert opinion. Subsequently, in order to generate a broader agreement and evaluation of ease of implementation, the majority of Portuguese MS consultants and departments of neuroradiology scrutinized and reviewed the consensus paper - comments and suggestions were considered. Timing and frequency of investigations, and other considerations such as MS criteria, were addressed in a separate paper.

RESULTS

Generic practical aspects of MRI protocols implementation

High-field MR imaging improves MS characterization, increasing lesion load quantification both on T2 weighted fluid attenuation inversion recovery (T2-FLAIR) and gadolinium-enhanced T1 weighted sequence and having a greater correlation with physical disability and cognitive measures. In patients with clinical isolated syndrome (CIS), the higher lesion load in 3T MRI units influenced the imaging classification of dissemination in space (but not in time) on first McDonald criteria. Until now, it has not been proved that the use of higher fields results in earlier diagnosis and we must consider that most Portuguese imaging centres are equipped with 1.5T scanners.

The application of advanced techniques in high-field and ultra-high-field scanners, such as susceptibility weighted imaging (SWI) and double-inversion recovery (DIR) may put in evidence characteristic features of multiple sclerosis plaques such as the perivenular distribution and cortical involvement, respectively, improving diagnostic specificity (see above).

The consensus recommendation is that it is mandatory to perform multiple sclerosis imaging at least in 1.5T MR unit. If the institution has a 3T MR scanner available, this may be preferably used, especially for brain imaging, but what is crucial is to guarantee that follow-up studies will be performed on the same magnetic field to allow an accurate comparison.

Regarding the spinal cord, the use of magnetic fields higher than 1.5T adds no diagnostic or prognostic value. Instead, the increase of $B_0$ generates more Gibbs artefacts and movement artefacts, from cerebrospinal fluid (CSF) pulsation and breathing, inducing false positives. It also results in higher energy deposit and consequent higher...
specific absorption rate, which can be partially compensat-
ed by fast parallel imaging.

All brain must be covered with axial slices, which should
be oriented parallel to the subcallosal line, both on 2D se-
quences and 3D sequences reformations. Precise and con-
sistent repositioning is fundamental for longitudinal eval-
uation of disease progression across time.

We recommend non-gapped slice thickness of ≤ 3 mm
and in-plane spatial resolution of 1 x 1 mm for brain studies.

For the spinal cord, sequences in sagittal planes should
be performed with non-gapped slice thickness of ≤ 3 mm
and in axial planes with non-gapped slice thickness of ≤ 5
mm.

Table 1 – Protocol for brain MRI at baseline and follow up)

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<tr>
<th>Brain MRI</th>
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<td><strong>Mandatory sequences</strong></td>
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<tr>
<td>Axial T2 axial</td>
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<tr>
<td>Axial PD and/or T2-FLAIR axial</td>
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<td>Sagittal T2-FLAIR (2D or 3D)</td>
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<td>Axial T1 SE 2D + gad</td>
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<th><strong>Optional sequences</strong></th>
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<tr>
<td>Axial T1 SE 2D</td>
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<td>3D T1-weighted sequences (particularly at 3T)</td>
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<td>Axial DWI</td>
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<td>DIR</td>
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<td>SWI</td>
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Non-gapped slice thickness of ≤ 3 mm and in-plane spatial
resolution of 1x1 mm. Gadolinium (single dose: 0.1 mmol/kg body weight) must be injected at least 5 minutes prior to T1 acquisition - we suggest injection before FLAIR to save time.

1.1 Proton Density (PD) / T2 WI and T2-FLAIR/DF

T2 weighted imaging (WI) sequences are imperative
in multiple sclerosis both for diagnosis and follow-up. This
should be acquired with a non-gapped slice thickness of ≤ 3
mm and in-plane spatial resolution of 1 x 1 mm. T2 and pro-
ton-density have better sensitivity for infra-tentorial lesions,
while T2-FLAIR allows better detection of perivenular and
juxtacortical lesions. In particular, sagittal T2-FLAIR is
useful to characterize disease affecting the corpus callosum
and to demonstrate the ovoid morphology of perivenular
lesions (‘Dawnson fingers’). Additionally, in areas particu-
larly susceptible to artefacts, such as temporal poles and
posterior fossa, we must confirm the presence of a demy-
elinating lesion in two T2-weighted sequences. Therefore,
we recommend axial planes of conventional spin-echo or
fast spin-echo T2 and proton-density (acquired with a dual
echo) and/or T2-FLAIR, combined with sagittal T2-FLAIR.

We highly recommend acquiring a 3D T2-FLAIR/dark fluid (DF) (1 mm³ isotropic voxel) followed by multiplanar
reconstructions on the axial plane with slice thickness of 3
mm without gap. The advantages of using a 3D T2-FLAIR
include: more homogenous CSF suppression, important
reduction of CSF and blood flow artefacts, and increased
posterior fossa lesion detection (equal or superior to T2-
weighted

Post-processing flexibility, including longitudinal
co-registration for subtraction images and automated lesion
segmentation, is an additional advantage.

We also suggest the use of coronal T2 FAT-SAT/ short
tau inversion recovery (STIR) for optic nerve evaluation in
case of optic neuritis clinical suspicion.

1.2 T1 weighted and contrast-enhanced

At 1.5T it is well established that conventional 2D
spin-echo sequences are more sensitive for identification
of active MS lesions enhanced with gadolinium. Axial T1
spin-echo images should be acquired with a non-gapped
slice thickness of ≤ 3 mm and in-plane spatial resolution

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1.5
The paradigm has been changing with technical developments including the wide implementation of single-slab 3D images, parallel imaging in higher field strengths, together with better receiver coil arrays and gradients. The higher field strength of 3T MRI scanners improves image resolution, allowing better detection of small lesions, and increases T1 shortening effect with gadolinium and higher detection rates of MS lesions compared to conventional 2D spin-echo at 3T. Also, 3D-GRE is less susceptible to pulsatile flow artefacts than 2D spin-echo. Other advantages of including a 3D-T1 sequence in the MS protocol are easier comparison on follow-up and possible co-registration of longitudinal studies with subtraction image, atrophy measure on T1 pre-contrast study (which ideally should be the same sequence as the post-contrast) and improved classification of cortical lesions. Also, we can obtain high-quality images at any plane by reformatting the generated data set.

Contrast administration is mandatory whenever lesions are detected on T2-weighted sequences, at least in the initial study to demonstrate dissemination in time. Gadolinium enhancing traduces breakdown of the blood-brain barrier caused by inflammatory activity, distinguishing chronic lesions from acute new lesions, in which enhancement may persist from three weeks to three months. The recommendation is a standard dose of gadolinium (single dose: 0.1 mmol/kg body weight) with a minimum delay of five minutes before acquisition. This time should be used to perform other sequences, namely T2/DP and/or T2-FLAIR, so that the total acquisition time is not extended.

In accordance with recent European Medicines Agency (EMA) recommendations, the use of gadolinium is now restricted to macrocyclic agents (gadobutrol, gadoteric acid and gadoteridol). These restrictions followed the emergence of several studies proving gadolinium deposition in brain tissues (see Gulani et al for a recent review) after the first description in 2014 of a relationship between cumulative dose of gadolinium and hyperintensity of dentate nucleus and globus pallidus. The Food and Drug Administration (FDA) also states “health care professionals should limit gadolinium-based contrast agents (GBCA) use to circumstances in which additional information provided by the contrast agent is necessary, and assess the necessity of repetitive MRIs with GBCAs.” Given these recent concerns, even though no data exists proving biological or neurological consequences from brain deposition of gadolinium, we should reconsider the administration of gadolinium as standard in follow up studies in multiple sclerosis. We can define disease activity by detecting new T2 lesions, although gadolinium administration improves sensitivity. The risk-benefit ratio in this group of patients must be cautiously evaluated. In a patient without clinical relapses or new MRI lesions for the last five years it may be reasonable to perform follow up studies without contrast administration. However, this aspect is still a matter of debate in the radiology community.

1.3 Diffusion-weighted imaging
Axial diffusion-weighted imaging (DWI) (≤ 5 mm) is mandatory in the imaging follow up for progressive multifocal leukoencephalopathy (PML) surveillance, a potentially devastating complication of therapy with natalizumab. PML is an opportunistic infection due to the reactivation and replication of the John Cunningham virus (JCV). Therefore, patients with detectable JCV serum antibodies are at higher risk and should follow a PML-surveillance algorithm described in the first part of these consensus recommendations. MRI has high sensitivity in the detection of PML lesions months before the first symptoms, and it has been shown that those patients that were asymptomatic at the time of PML diagnosis had less functional disability and higher survival. DWI hyperintensity is considered a very helpful feature for diagnosing PML, reflecting acute demyelination with consequent swelling of oligodendrocytes and astrocytes. However, we should be aware that high signal intensity in DWI might be absent in 40% of the pre-symptomatic patients, particularly in smaller and/or cortical lesions.

We highly recommend the use of DWI in the core MR protocol of the first examination to exclude non-MS lesions, in particular differentiating it from acute ischemia. Indeed, most MS acute and chronic MS lesions have increased ADC values, largely due to extracellular oedema and axonal loss. However, in a subgroup of patients, we may also find hyperacute demyelinating lesions with transient diffusion restriction. DWI cannot replace gadolinium-enhanced T1WI for the distinction between acute and chronic lesions.

1.4 Optional sequences
a) SWI and other susceptibility-based techniques
MRI techniques susceptible to iron in deoxygenated
haemoglobin (SWI and T2*) made accessible in vivo the typical perivenous morphology of MS lesions, already known from histological data. This was first demonstrated on T2* at 7T and the same group proved further that this perivenous appearance was predictive of demyelination vs non-MS white matter lesions. In order to simultaneously highlight white matter lesions and veins, MR imaging contrast techniques were developed combining a single image 3T-FLAIR and 7T-SWI phase data or T2* and FLAIR (both at 3T) called FLAIR*. This last technique was recently applied in a clinical dataset at 3T showing 100% of sensitivity and 80% of specificity for more than 45% of ‘vein in lesion’, while dissemination in space (DIS) criteria had 96% sensitivity and 40% specificity. The FLAIR* technique uses a T2*-weighted segmented echo-planar imaging (T2*-segEPI) acquired during contrast injection (single-dose), using the paramagnetic properties of gadolinium to compensate for the less sensitivity to susceptibility effects at 3.0 T compared to 7.0 T. Furthermore, MS lesions also exhibit a characteristic rim or nodular low signal on susceptibility-based sequences, which may help to differentiate CIS or MS from other neurological disorders.

The inclusion of susceptibility-based techniques as an optional sequence on the first diagnostic may be useful for the differential diagnosis. FLAIR* is not available in most Portuguese imaging centres, but is possible to have a perception of the “vein in lesion” by merging 3D FLAIR and SWI (Fig. 1).

b) DIR or PSIR

Cortical lesions are typical and abundant on MS, as shown by histopathological data. MRI techniques allow assessment in vivo and characterization of grey matter pathology in MS in such a way that cortical lesions were included on 2016 MAGNIMS criteria and on the recently revised McDonald criteria (2017). DIR is one of those sequences that improves the detection of cortical lesions, in this case by suppressing signals from white matter and CSF. On the other hand, DIR is susceptible to flow-related artefacts and variations on grey matter signal intensity, leading to frequent false positives and low interobserver concordance.

Phase-sensitivity inversion recovery (PSIR) seems to improve detection and classification of intracortical lesions when combined with DIR, even though lesions with minimal extension into the white matter still remain difficult to classify, even with this combined protocol. In this context, 3D MPRAGE provides additional information to improve lesion classification, with the advantage of being widely available in most manufacturers without additional cost and, consequently, being easily implemented in clinical practice. Any of these sequences may be included as optional on the MS protocol at 3T since cortical lesions can now be used to fulfil MRI criteria for DIS. However, they are not considered mandatory since we must be aware that MR capacity for detection of grey matter pathology is far below the gold standard of histopathology and we lack standardization of image acquisition and image analysis of cortical lesions with specific imaging criteria. Furthermore, DIR and PSIR are not universally available in Portuguese imaging centres.

Recommendations summary

MRI protocols for diagnosis and follow-up (optional sequences)

- Optional: SWI and DIR may be included on the MS protocol as optional sequences.

1.5 Spinal cord imaging protocol

Spinal cord MRI imaging is prone to different types of artefacts, being technically challenging and sometimes difficult to interpret not only because spinal cord has a small cross-sectional area, which is surrounded by a high amount of fat, bone, CSF and vessels, but also because spinal cord imaging is susceptible to both participant movements and
intrinsic motion promoted by cardiac and respiratory cycles. Nevertheless, spinal cord imaging significantly adds diagnostic and prognostic value in MS, with asymptomatic lesions being detected in 42% of patients with CIS. 35 The presence of spinal cord MS lesions may also contribute to fulfill the 2017 McDonald criteria for space and time dissemination 31 and to predict conversion to clinically definite MS. 21 Specific indications on the frequency and timing to perform spinal cord MRI were also stated in the first part of these guidelines 2.

Protocol for spinal cord MRI is summarized in Table 2.

1.5.1 T2 weighted
Sagittal planes are the main approach in spinal cord imaging since they allow an extensive coverage of the cervical and/or dorsal segments with a reasonable acquisition time compared to axial planes. However, sagittal imaging is also more susceptible to artefacts that can easily lead to false positives. Conventional spin-echo or fast spin-echo T2 is considered the reference standard, always being part of the protocol. But, it is generally recognized that these conventional sequences lack sensitivity and specificity for MS lesions. 35-38 It is mandatory to complement conventional T2-weighted sequence with a proton-density or a STIR sequence (Fig. 2). STIR has a higher contrast-to-noise ratio, making the lesions ‘brighter’, but it is also more affected by flow-related artefacts, frequently leading to the identification of erroneous lesions. That is, compared to proton-density, STIR has higher sensitivity but lower specificity.

More recently, an alternative to STIR in the cervical segment (where flow-related artefacts become more problematic) is PSIR, which has an excellent lesion-to-cord contrast ratio. However, it is not as widely available in our healthcare institutions and, although it performs slightly better than STIR in cervical cord, 39,40 it is far less sensitive in the dorsal segment. 40

In the axial plane, it is important to perform high-resolution sequences (pixel size ≤ 1 mm2) due to the small cross-sectional area of spinal cord. 41,42 It is common to use T2-weighted gradient echo sequences with short echo time in order to reduce CSF flow artefacts and acquisition time, especially in the cervical segment. Although more time-consuming, thin-slice T2-weighted fast-spin echo sequences (2D or 3D) are also appropriate to increase detection of MS lesions, particularly in the dorsal segment. Axial T2 WI should be performed for better characterization of lesions suspected/detected on sagittal planes.

In conclusion, we can only define a spinal cord lesion if we detect a hyperintense area 1) in the sagittal plane both
on T2 and another appropriate sequence (STIR, DP, PSIR) or 2) if we identify it in two T2 weighted planes.\textsuperscript{31}

**Recommendations summary**

**Spinal cord MRI imaging (T2 weighted)**

- Mandatory: It is mandatory to obtain at least two T2 weighted sequences in the sagittal plane, and they must include a conventional spin-echo or fast spin-echo T2 plus proton-density-weighted (acquired with a dual-echo) or short-tau inversion recovery sequences (STIR).
- Mandatory: If spinal cord lesions are detected on sagittal plane sequences, it is mandatory to include a focussed axial T2-weighted sequence.

### 1.5.2 T1 weighted

Only a small number of spinal cord lesions enhances after gadolinium administration compared with the brain (four to ten times more common) and are usually related to new clinical symptoms.\textsuperscript{31,41} We recommended acquiring a sagittal contrast-enhanced T1-weighted spin-echo, when T2 lesions are present, if possible in the same session as brain MRI. This will save time and reduce the number of gadolinium administrations and its potential adverse effects in these chronic patients (as discussed in 2.1.2). Axial contrast-enhanced T1-weighted spin-echo acquisition is optional.

MS abnormalities are rarely seen on spontaneous sagittal T1-weighted imaging, adding no significant value to the standard protocol regarding spinal cord evaluation.\textsuperscript{42} In order to facilitate the lesion enhancement depiction, the acquisition of a conventional (sagittal) 2D T1 spin-echo before gadolinium injection may be useful.

**Recommendations summary**

**Spinal cord MRI imaging (T1 weighted)**

- Mandatory: It is mandatory to obtain a sagittal contrast-enhanced T1-weighted spin-echo when spinal cord MS T2 lesions are identified on spinal imaging.
- Highly recommended: It is highly recommended to follow the “one-stop-strategy”: include a contrast-enhanced T1-weighted spin-echo when brain MS T2 lesions are identified in brain imaging.
- Optional: We suggest that a conventional sagittal 2D T1 spin-echo should be obtained before gadolinium injection to facilitate MS lesion enhancement depiction.

### 2. Advanced techniques

In the past years, the great advance in acquisition and analysis of non-conventional MR imaging encouraged the publication of several MS studies using those advanced techniques to better characterize both the pathophysiology at tissular/microscopical level and the prognosis in a more individualized manner.

Magnetization transfer imaging (MTI), based on the exchange of magnetization between pools of bound and free-protons,\textsuperscript{43} provides quantitative metrics sensitive to neurodegenerative microstructural changes on MS, in contrast to conventional techniques that predominantly reflect the inflammatory aspect of the disease.\textsuperscript{44} This method is easy to implement in the clinical setting, but it lacks specificity, widely changing with biophysical parameters and between scanners.\textsuperscript{43,44}

Myelin-water imaging (MWI) is a multi-echo T2 relaxation technique that assesses water trapped in myelin bilayers. It quantifies the myelin content, with strong histopathological correlations,\textsuperscript{45} which was shown to be heterogeneously reduced in different MS-lesion type and even in normal-appearing white matter (NAWM).\textsuperscript{46} There are several potential confounding factors that may influence this quantitative data and difficult MWI clinical implementation,\textsuperscript{47} even though recent advances allowed shorter acquisition times and whole-brain coverage.\textsuperscript{43}

The integrity of white matter tracts can be assessed by diffusion tensor imaging (DTI) and seems to be linked with cognitive impairment and progression of physical disability.\textsuperscript{43}

MR spectroscopy may also contribute to the assessment of axonal damage, with NAA decreases consistently reported, and to study grey matter pathology, nowadays recognized as significant in MS.\textsuperscript{48} Both have unsolved technical issues that compromise reproducibility and translation to clinical practice.

Perfusion, both arterial spin labelling (ASL) and dynamic susceptibility contrast (DSC), has produced contradictory results\textsuperscript{43} and has no place in routine imaging evaluation of MS patients (except in case of tumefactive demyelinating lesions, in which perfusion can be useful for differential diagnosis with neoplasms).\textsuperscript{49}

Functional MRI (fMRI) has proved to be an interesting tool to assess adaptive cortical changes/reorganization that may limit the clinical impact of structural injury.\textsuperscript{50} fMRI applications are presently limited to group studies, in research or, eventually, clinical trials, and does not have a role in clinical practice.

In conclusion, despite being theoretically appealing, most MR advanced techniques are technically complex, time-consuming and difficult to implement outside the research framework.

Imaging postprocessing methods, specially automated methods, to measure brain atrophy progression (longitudinal volumetric studies) or to perform automatic lesion count (including subtraction images and automatic and semiautomatic segmentation) may be included only as an aid to our imaging evaluation in clinical practice, taking into account that they are not formally approved yet and still have some limitations. In addition, neuroradiologists must have the expertise and the hospitals/imaging centres need to provide access to the tools demanded for this type of evaluation.
CONCLUSION
In these first Portuguese MRI consensus recommendations, we provide standard imaging protocols adapted to the Portuguese reality, based on the most recent scientific evidence and our own practical experience. The harmonisation of MRI protocols throughout imaging centres will allow a better diagnostic acuity and precise follow-up of the disease. Due to the great technical advances in MRI and in MS knowledge, these guidelines must be reviewed periodically.

OBSERVATIONS
The Grupo de Estudos de Esclerose Múltipla (GEEM, the main Portuguese healthcare professionals group dedicated to MS study and treatment, supported by the Portuguese Neurological Society) experts group for the first

Table 3 – Guidelines for the neuroimaging report

1. Technique
- Magnetic field strength;
- Anatomic coverage (brain or spinal cord and which segment);
- MR sequences and planes acquired (including thickness);
- Gadolinium-based agent and dose;
- Availability and date of a previous brain and/or spinal MR exam for comparison.

2. Imaging findings
- Number (count if ≥ 3 mm) and anatomical distribution of T2 lesions, specifying if juxtacortical/cortical, periventricular, infratentorial or in spinal cord;
- Number and anatomical distribution of gadolinium-enhancing T1 lesions and type of enhancement (ring, solid, concentric, etc.);
- Atrophy characterization with the use of validated clinical imaging scales, such as global cortical atrophy (GCA) scale. The qualitative impression of the initial atrophy and/or atrophy progression should be included;
- Incidental/non-MS related findings and its clinical significance;
- Follow-up: new T2 lesions, gadolinium-enhancing T1 lesions and increased size of previously detected MS plaques.

3. Conclusion
- Interpret if findings are typical, atypical or not consistent with MS and, in this case, provide differential diagnosis;
- Indicate if MR criteria of DIS and dissemination in time (DIT) are fulfilled according to the 2017 MS McDonald criteria;
- Follow-up: conclude if there are imaging signs of new silent lesions or active plaques and identify potential therapeutic adverse effects (particularly, PML-IRIS).

Portuguese Consensus Recommendations for the Use of the Magnetic Resonance Imaging in Multiple Sclerosis in Clinical Practice is composed by: Pedro Abreu, Rui Pedroza, Maria José Sá, João Cerqueira, Lívia Sousa, Ana Martins da Silva, Joaquim Pinheiro, João de Sá, Sónia Batista, Rita Moiron Simões, José Vale.

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COMPETING INTERESTS
The authors have declared that no competing interests exist.

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