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Magnetic Resonance Imaging in Multiple Sclerosis: An Analysis of the Implementation of the Portuguese Consensus

Ressonância Magnética na Esclerose Múltipla: Uma Análise da Implementação do Consenso Português

Alyne CORDEIRO*[1], Ana João MARQUES*[2], Ana Rita CASTRO*[3], Cristiana SILVA*[4], Duarte CARAPINHA*[5], Francisca FERREIRA*[6,7], Miguel SCHÖN*[8], Daniela JARDIM PEREIRA[9], João Paulo GABRIEL[2], Luís RUANO[3,10,11], Mariana SANTOS[5], Miguel GRUNHO[1,12], Mónica SANTOS[8], José VALE[13], Maria José SÁ[14], Ricardo SOARES DOS REIS✉[6,7]
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ABSTRACT

Introduction: Magnetic resonance imaging (MRI) plays a critical role in diagnosing and monitoring people with multiple sclerosis (MS). The 2020 Portuguese Consensus on Magnetic Resonance Imaging in Multiple Sclerosis aimed to standardize MRI use. This study evaluated the implementation of the consensus in clinical practice.

Methods: This is an observational, retrospective, longitudinal and multicentric study comprising patients diagnosed with MS between 2019 and 2022 from seven hospital centers in Portugal. We collected demographic data and details regarding MRI requests, protocols, and reports. We performed descriptive and comparative analyses between the period before and after guideline publication.

Results: We included 242 patients, mainly female (66.0%), with a mean age of 37 (SD 13). A total of 989 MRIs were performed, 69.1% follow-ups, 68.1% brain MRIs, and 31.9% spinal cord MRIs. Around half of the MRI requests fulfilled all the recommended information. All mandatory sequences in the neuroimaging protocol were performed in 82.5% of brain MRIs and 71.1% of spinal cord MRIs. None of the reports fulfilled all the suggested parameters. Magnetic resonance imaging technical description and imaging findings had the least compliance, mainly concerning gadolinium information (0.85%), lesion load (18.6%), and atrophy characterization (27.1%). After the implementation of the consensus, physicians reported the MS phenotype more often ($p < 0.05$) and neuroradiologists reported more technical parameters ($p < 0.05$). When MRIs were performed in a private setting, neuroimaging protocols were similar, but the reports fulfilled more frequently the suggested topics regarding the conclusion ($p < 0.05$).

Conclusion: This study suggests incomplete adherence to the Portuguese Consensus on MRI in MS. Information provided by the physician in MRI requests was often insufficient, which could hamper MRI protocol planning. Magnetic resonance imaging reports were frequently lacking relevant information for the diagnosis and follow-up of MS patients. Further efforts are needed to ensure full implementation and optimize MS care.

Keywords: Consensus; Magnetic Resonance Imaging; Multiple Sclerosis/diagnostic imaging; Portugal

RESUMO

Introdução: A ressonância magnética (RM) tem um papel crucial no diagnóstico e monitorização dos doentes com esclerose múltipla (EM). Este estudo pretende avaliar a implementação das Recomendações e Consensos do Grupo de Estudos de Esclerose Múltipla e da Sociedade Portuguesa de Neurorradiologia sobre Ressonância Magnética na Esclerose Múltipla na prática clínica.

Métodos: Realizou-se um estudo observacional, retrospetivo, longitudinal e multicêntrico englobando doentes com diagnóstico de EM entre 2019 e 2022 de sete hospitais portugueses. Foi obtida informação demográfica e dados relativos à requisição da RM, protocolos de aquisição e relatório. Foi realizada análise descritiva e comparativa.

Resultados: Foram incluídos 242 doentes, sendo 66% do sexo feminino. A média de idades ao diagnóstico foi 37 (DP 13) anos, predominando as formas surto-remissão (225, 93%). Foram incluídos 989 exames, correspondendo a 737 pedidos e relatórios. Um terço dos relatórios estava indisponível na data pretendida, com implicações em 83,7% dos casos, sendo a principal uma nova consulta (58,9%). Todos os critérios recomendados foram cumpridos por 28,8% das requisições de RM diagnósticas e 3,7% de seguimento. Todas as sequências obrigatórias foram executadas em 82,5% das RM crânio-encefálicas e 71,1% das RM medulares. Nenhum dos relatórios cumpriu todos os parâmetros recomendados, destacando-se a omissão mais frequente da dose de gadolínio, carga lesional e caracterização da atrofia cerebral. Após implementação das recomendações, os neurologistas reportaram com maior frequência o fenótipo da doença ($p < 0{,}05$) e os neurorradiologistas os parâmetros técnicos ($p < 0{,}05$). Os exames realizados em hospitais privados apresentaram protocolos de neuroimagem semelhantes, cumprindo mais frequentemente os tópicos sugeridos na conclusão dos relatórios ($p < 0{,}05$).

*: Co-first authors.
1. Neurology Department. Unidade Local de Saúde Almada-Seixal. Almada. Portugal.
2. Neurology Department. Unidade Local de Saúde de Trás-os-Montes e Alto Douro. Vila Real. Portugal.
3. Neurology Department. Unidade Local de Saúde Entre Douro e Vouga. Santa Maria da Feira. Portugal.
4. Neurology Department. Unidade Local de Saúde de Coimbra. Coimbra. Portugal.
5. Neurology Department. Unidade Local de Saúde de Amadora/Sintra. Amadora. Portugal.
6. Neurology Department. Unidade Local de Saúde São João. Porto. Portugal.
7. Department of Clinical Neurosciences and Mental Health. Faculdade de Medicina da Universidade do Porto. Porto. Portugal.
8. Neurology Department. Unidade Local de Saúde de Santa Maria. Lisbon. Portugal.
9. Neurorradiology Department. Unidade Local de Saúde de Coimbra. Coimbra. Portugal.
10. Department of Medical Sciences. Universidade de Aveiro. Aveiro. Portugal.
11. Institute of Public Health and Laboratory for Integrative and Translational Research in Population Health (ITR). Universidade do Porto. Porto. Portugal.
12. Egas Moniz Center for Interdisciplinary Research (CiiEM). Egas Moniz School of Health & Science. Caparica. Almada. Portugal.
13. Neurology Department. Unidade Local de Saúde de Loures/Odivelas. Lisbon. Portugal.
14. Faculdade de Ciências da Saúde. Universidade Fernando Pessoa. Porto. Portugal.
✉ **Autor correspondente:** Ricardo Soares-dos-Reis. r.soaresdosreis@gmail.com
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Conclusão: Este estudo sugere uma adesão incompleta ao Consenso Português sobre RM na EM. A informação fornecida pelo clínico foi frequentemente insuficiente, o que poderá comprometer a planificação do protocolo de RM. No relatório havia regularmente informação relevante em falta relativa ao diagnóstico e seguimento dos doentes. São necessários esforços adicionais para garantir a implementação completa e otimizar os cuidados na EM.
Palavras-chave: Consenso; Esclerose Múltipla/diagnóstico por imagem; Portugal; Ressonância Magnética

KEY MESSAGES

- The study provides a detailed real-world evaluation of compliance with national MRI guidelines for MS. The multicenter design and large sample size enhance the generalizability of findings across Portuguese MS centers.
- Data show clear areas of underperformance, particularly in MRI request completeness and reporting quality.
- Retrospective design and non-random sampling may introduce selection bias and limit causality inference.
- Further measures should be taken to increase compliance, namely improving MRI request completeness.

INTRODUCTION

Multiple sclerosis (MS) is a chronic inflammatory autoimmune disorder of the central nervous system, primarily affecting young adults and causing significant disability. In Portugal, the prevalence of MS is estimated at 64.4 per 100 000 inhabitants.[1]

Magnetic resonance imaging (MRI) plays a fundamental role in MS, being essential not only for diagnosis – particularly after its incorporation into the McDonald Criteria in 2001 and subsequent refinement in the 2017 revision – but also for prognostic assessment, treatment monitoring, and detection of potential therapy-related complications.[2-4]

In Portugal, a panel of experts, comprising neurologists and neuroradiologists, developed a consensus on MRI use in people with MS (pwMS), with recommendations published in 2018 for diagnosis and follow-up, and in 2020 for imaging protocols and reporting standards.[5,6] While aligned with international guidelines, such as those from the Magnetic Resonance Imaging in Multiple Sclerosis (MAGNIMS) network, the Portuguese consensus aimed to address specific national challenges.[4-6]

The primary objective of our study was to evaluate the implementation of these recommendations in routine MS care across Portuguese neurology centers. The secondary objectives were to compare the period before and after the MRI guideline publications and to analyze the discrepancy in compliance between public and private settings.

METHODS

Study population and participating centers

We performed an observational, retrospective, longitudinal and multicentric study comprising pwMS from seven hospital centers in Portugal: Unidade Local de Saúde (ULS) Almada-Seixal; ULS de Amadora/Sintra; ULS de Coimbra; ULS Entre Douro e Vouga; ULS de Santa Maria; ULS São João and ULS de Trás-os-Montes e Alto Douro. We included adults who were newly diagnosed with MS between February 1st, 2019, and December 31st, 2022, according to the McDonald 2017 Criteria.[3] We established an inclusion ceiling of 30 pwMS for centers with a lower patient volume, which represented approximately 10% of the total MS population followed at those centers. In centers with a higher patient volume, the inclusion ceiling was 50 pwMS, accounting for, at most, 10% of their MS population. Data was systematically collected retrospectively using clinical records until this number was reached. Patients with missing information regarding the time of diagnosis, or whose MRI requests, images or reports could not be accessed were excluded.

Clinical and radiological assessment

For each selected patient, demographic data were collected, including age at initial diagnosis, sex, specific subtype of multiple sclerosis [relapsing-remitting multiple sclerosis (RRMS), secondary progressive multiple sclerosis (SPMS), primary progressive multiple sclerosis (PPMS)], date of diagnosis, and final diagnosis at the time of data collection. We included information regarding all MRI scans performed and reported both in public and private settings for each selected patient.

Details regarding MRI requests by the neurologist as well as MRI protocols and reports by the neuroradiologist were collected for every MRI scan performed by each patient between the time of diagnosis and the moment of data acquisition. The data collection and subsequent presentation of the results was based on the points described in the Consensus Recommendations of the MS Study Group and Portuguese Society of Neuroradiology for the Use of the Magnetic Resonance Imaging in Multiple Sclerosis in Clinical Practice.[5,6]

Data was categorized into three groups: clinical information provided by physicians in MRI request; protocol for brain and spinal cord (SC) MRI at baseline and follow-up; and neuroimaging report. The variables were treated as dichotomous variables (present or absent).

Regarding clinical information for diagnostic MRI, the variables included date of symptom onset and evolution, description of main clinical signs, clinically important information and special precautions. For follow-up MRI the variables were the purpose of follow-up, diagnosis description, description of important clinical information, treatment information and special precautions.

Finally, neuroimaging report variables were divided into three areas according to the guidelines for a structured neuroimaging protocol, namely, technique (magnetic field strength, anatomic coverage, MRI sequences, gadolinium-based agent and dose, availability and date of previous test), imaging findings (lesion number and anatomical distribution, lesion load, atrophy, incidental findings, follow-up), and conclusion (interpretation, whether MRI criteria of dissemination in space (DIS) and dissemination in time (DIT) are fulfilled, follow-up conclusion).

Guideline compliance was obtained in each patient as the percentage of topics mentioned for each category in requests and reports, as well as mandatory brain MRI and SC MRI sequences performed. The specificities of the recommendations for each category are detailed in the Results section.

When MRI requests or reports included both brain and SC imaging, they were considered a single scan for details such as MRI request information and timing of MRI reports, but as separate scans for imaging protocols.

Data was stored in an anonymized and protected database with access restricted to the investigators. The study protocol was approved by each center's local ethics committee.

Statistical analysis

Data analysis was conducted using Statistical Software for Data Science (Stata) 14®. Continuous variables were reported as mean ± standard deviation or median (interquartile range), and categorical variables as frequency and percentage. Appropriate statistical tests were chosen based on distribution curves. Group differences were analyzed using the Mann-Whitney or chi-square tests, as appropriate ($p < 0.05$ for significance). Nonparametric tests were used to assess compliance with Portuguese guidelines, before and after publication of the second part in 2020. We used univariate linear and binary logistical regression to assess whether higher compliance with the guidelines in the request form was associated with higher compliance in the imaging sequences/report. For logistic regression compliance was converted into a dichotomous variable (full *versus* not full compliance) and used as the dependent variable. For multivariate logistic regression, a dichotomous variable reflecting MRIs fully performed in the public sector was added as independent variable. For linear regression compliance percentage was treated as continuous variable, either as a dependent or independent variable. We used the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (HETTEST) and assessed collinearity using the variance inflation factor (VIF).

RESULTS

From February 1st, 2019, to December 31st, 2022, we enrolled 242 eligible patients, of whom 160 (66.0%) were female. The mean age at diagnosis was 37 ± 13 years. The final diagnosis was RRMS in 225 patients (93.0%), PPMS in 12 (5.0%), and SPMS in 5 (2.0%). The number of patients included in each center and their year of diagnosis are shown in Table 1. We included 732 MRI requests and reports, with a mean of 3 ± 1 MRI requests per patient. Among these, 369 (50.4%) were performed and reported in the requesting hospital, while 311 (42.4%) were performed and reported externally, and 52 (7.1%) were conducted in the requesting hospital but reported externally. Thus, we included a total of 989 MRIs: 674 were brain MRIs (68.1%) and 315 were SC MRIs (31.9%). From these, 306 (30.9%) were diagnostic MRIs and 683 (69.1%) were follow-up MRIs (Table 1).

We observed that 469 MRIs (81.4%) were undertaken before the subsequent outpatient appointment. The median time between request and scan was 130 (57 - 195) days. Nearly a third (172, 30.2%) of the follow-up MRIs did not have the report available for the appointment. The median time between the MRI request and the report was 141 (68 – 203) days. The unavailability of MRI results had consequences in 85.3% of those cases, resulting in rescheduled appointments (117 cases, 68.4%), delayed treatment switches (21 cases, 12.3%), delayed diagnosis (seven cases, 4.1%), and delayed adverse event identification (one case).

Concerning diagnostic MRI requests (Table 2), 60 cases (28.8%) contained all the suggested required information, with an average compliance rate of 64.6% (SD 2.8%). The date of symptom onset and evolution was the least mentioned topic (95 tests, 45.7%). In follow-up studies, 19 (3.7%) requests completely met the proposed information requirements, with an average compliance rate of 52.2% (SD 1.9%). The least fulfilled topics for follow-up studies were John Cunningham virus serostatus and previous treatment/immunosuppression regarding progressive multifocal leukoencephalopathy (PML) surveillance (24, 6.3%), followed by duration of treatment (111, 21.6%) and the date and clinical information from the last MRI (130, 25.5%).

Information on special needs, such as claustrophobia and potential allergies, was present in 66.0% of cases. However, three centers had a mandatory checklist (n = 385 scans). In centers without a checklist, 28.2% of MRI requests detailed this information.

Table 1 – Demographic and clinical characteristics of the study population (n = 242)

Characteristics	
Sex, n (%)	
Female	160 (66.1)
Age at diagnosis, mean (SD)	36.87 (12.58)
Hospital, n (%)	
ULSUC	50 (20.7)
ULSSJ	50 (20.7)
ULSTMAD	39 (16.1)
ULSEDV	30 (12.4)
ULSA/S	30 (12.4)
ULSASI	30 (12.4)
ULSSM	13 (5.4)
Diagnosis, n (%)	
RRMS	225 (93.0)
PPMS	12 (5.0)
SPMS	5 (2.1)
Year of diagnosis, n (%)	
2019	53 (21.9)
2020	65 (26.9)
2021	73 (30.2)
2022	51 (21.0)
Number of MRI requests per patient, mean (SD)	3.03 (1.47)
Total number of MRIs performed, n (%)	989 (100.0)
Diagnostic MRI, n (%)	277 (28.0)
Brain MRI	166 (16.7)
Spinal cord MRI	111 (11.2)
Follow-up MRI, n (%)	712 (72.0)
Brain MRI	508 (51.4)
Spinal cord MRI	204 (20.6)

SD: standard deviation; ULSEDV: Unidade Local de Saúde Entre Douro e Vouga; ULSTMAD: Unidade Local de Saúde de Trás-os-Montes e Alto Douro; ULSUC: Unidade Local de Saúde de Coimbra; ULSSM: Unidade Local de Saúde de Santa Maria; ULSSJ: Unidade Local de Saúde São João; ULSA/S: Unidade Local de Saúde Almada-Seixal; ULSASI: Unidade Local de Saúde de Amadora/Sintra; PPMS: primary progressive multiple sclerosis; SPMS: secondary progressive multiple sclerosis; RRMS: relapsing-remitting multiple sclerosis

Regarding neuroimaging protocol and MRI sequences (Table 3), all brain MRI mandatory sequences were performed in 556 (82.5%) MRIs, with an average compliance rate of 95.7% (SD 1.3%). The least performed mandatory sequence was sagittal T2-fluid attenuated inversion recovery (FLAIR) (90.2% overall; 81.3% diagnostic, 93.4% follow-up, $p < 0.01$). The most performed optional sequences were axial diffusion-weighted imaging (F) in 630 MRIs (93.6%), axial spin-echo (SE) T1 2D in 492 (73.1%) and 3D T1-weighted sequences in 296 (44.0%). Double inversion recovery sequence (DIR) was applied in 17 cases (2.5%). For SC MRI, all mandatory sequences were performed in 224 MRIs (71.1%), with an average compliance rate of 95.7% (SD 1.5%). The most performed optional sequence was sagittal SE T1 (273 studies, 86.9%), while the least performed was phase-sensitive inversion recovery (PSIR), in two MRIs.

None of the reports fulfilled all the suggested parameters across the three proposed criteria (technique, imaging findings and conclusion). Concerning MRI technique description, one (0.5%) diagnostic and three (0.6%) follow-up reports covered all suggested topics. The average compliance rate was 49.2% for diagnostic and 61.4% for follow-up reports, with gadolinium-based agent dosing being the least reported (0.5% diagnostic, 1.2% follow-up) together with magnetic field strength (12.6% diagnostic, 18.1% follow-up). Regarding imaging findings, seven (3.3%) diagnostic and 39 (7.5%) follow-up reports described all suggested

Table 2 – Diagnostic and follow-up MRI requests (n = 732)

Diagnostic MRI requests (n = 214)	**Yes, n (%)**
Date of symptom onset and evolution	95 (45.7)
Description of main clinical signs and clinical information	182 (87.9)
Description of special needs and potential allergies or other relevant information	126 (60.9)
All suggested topics regarding diagnostic MRI requests mentioned	60 (28.8)
At least 1 suggested topic regarding diagnostic MRI requests missing	148 (71.2)
Mean % suggested topics regarding diagnostic MRI requests mentioned, mean (SD)	64.6% (0.3)
Follow-up MRI requests (n = 518)	
Purpose of follow-up scan	502 (97.5)
Description of diagnosis	481 (93.4)
Description of clinical information considered important	236 (45.9)
DMT description	326 (63.3)
Duration of treatment	111 (21.6)
Information regarding PML surveillance study	24 (6.3)
Date and, if considered relevant, clinical information of last MRI performed	130 (25.5)
Description of special needs and potential allergies or other relevant information	342 (66.0)
All suggested topics regarding follow-up MRI requests mentioned	19 (3.7)
At least 1 suggested topic regarding follow-up MRI requests missing	496 (96.3)
Mean % suggested topics regarding follow-up MRI requests mentioned, mean (SD)	52.2% (0.2)

DMT: disease modifying treatment; PML: progressive multifocal leukoencephalopathy; SD: standard deviation

topics, with an average compliance rate of 51.8% for both. Regarding diagnostic studies, the least mentioned topics were subjective evaluation of lesion load (18.6%) and atrophy characterization (27.1%). Follow-up reports showed a similar pattern. In the conclusion section, 41 diagnostic reports (19.2%) and 165 follow-up reports (31.9%) included all suggested topics, with average compliance rates of 47.0% (SD 0.5%) and 50.1% (SD 0.4%), respectively. The least reported topics were MRI criteria of DIS and DIT in diagnostic MRIs (17.2%) and imaging signs of disease progression in follow-up MRIs (35.2%) (Table 4).

When comparing all MRI examinations before and after the implementation of the recommendations (Table 5), our analysis focused on MRI requests, neuroimaging protocols, and MRI reports.

Concerning requests, only the specification of the MS phenotype in follow-up MRI requests was significantly different (71.0% before, *vs* 94.0% after the recommendations, $p < 0.001$). Analysis of neuroimaging protocols did not yield any statistically significant differences between these two periods. For MRI reports, a higher percentage lacked sequence descriptions after the recommendations (7.8% before *vs* 11.1% after, $p = 0.01$). Additionally, reports more often omitted lesion number (49.4% before *vs* 61.5% after, $p = 0.039$) and location details (3.9% before *vs* 19.8% after, $p = 0.002$). The proportion of technical parameters mentioned was higher post-recommendations (51.7% before, *vs* 58.5% after, $p < 0.001$).

We also compared neuroimaging protocols, reports and the timeliness of response (i.e., whether the MRI was performed before the appointment and if the report was available) from public hospitals and private settings (Table 6). Magnetic resonance imagings performed at the requesting hospital were less often available at the intended time compared to those performed elsewhere (78.5% *vs* 84.9%, $p = 0.047$), with a median time from MRI request to MRI scan of 146 (68 – 200) *vs* 86 (36 - 161) days, respectively ($p < 0.001$). The median time from MRI request to availability of MRI reports was 162 (77 - 204) days in public settings and 94 (49 - 179) days in private settings ($p < 0.001$). Report availability for the next appointment was not different (67.2% *vs* 72.9%, $p = 0.14$).

Public hospitals fully complied with all mandatory brain MRI sequences more often than private settings (85.1% *vs* 79.0%, $p = 0.04$), despite comparable mean execution percentages (96.2% in public *vs* 95.1% in private, $p = 0.28$). Private settings had higher percentages of mandatory T2-FLAIR axial acquisitions (99.4% *vs* 96.7%, $p = 0.011$) for brain MRI protocols, but were outperformed by public hospitals in optional T1 3D (62.8% *vs* 18.6%, $p < 0.001$), T1 axial

Table 3 – Neuroimaging protocols and MRI sequences (n = 989)

Brain MRI (n = 674)	**Yes, n (%)**
Mandatory sequences	
Axial T2	667 (99.0)
Axial PD and/or T2-FLAIR	661 (98.1)
Axial T1 SE 2D + gad	615 (91.2)
Sagittal T2-FLAIR (2D or 3D)	608 (90.2)
All mandatory sequences performed	556 (82.5)
At least 1 mandatory sequence not performed	118 (17.5)
Mean % mandatory sequences performed, mean (SD)	95.7% (0.1)
Optional sequences	
Axial DWI	630 (93.6)
Axial T1 SE 2D	492 (73.1)
3D T1-weighted sequences	296 (44.0)
SWI	268 (39.8)
DIR	17 (2.5)
Spinal cord MRI (n = 315)	
Mandatory sequences	
Sagittal T2 SE or FSE	305 (96.8)
Axial T2	291 (92.4)
Sagittal T1 SE + gad	284 (90.2)
Sagittal PD (acquired in dual echo) or STIR	275 (87.3)
All mandatory sequences performed	224 (71.1)
At least 1 mandatory sequence not performed	91 (28.9)
Mean % mandatory sequences performed, mean (SD)	92.7% (0.1)
Optional sequences	
Sagittal T1 SE	273 (86.9)
Axial T1 SE + Gad	205 (65.1)
Axial 2D or 3D T2 FSE	98 (31.1)
PSIR	2 (0.6)

DIR: double inversion recovery sequence; DWI: diffusion-weighted imaging; FLAIR: fluid attenuated inversion recovery; FSE: fast spin-echo; Gad: gadolinium; PSIR: phase-sensitive inversion recovery; SE: spin-echo; SD: standard deviation

SE 2D (80.9% *vs* 62.5%, $p < 0.001$), susceptibility weighted imaging (SWI) (48.6% *vs* 27.7%, $p = 0.010$), and DIR acquisitions (3.9% *vs* 0.7%, $p = 0.010$). Regarding SC MRI, public hospitals conducted a higher percentage of PD sagittal or STIR mandatory sequences (94.7% *vs* 78.9%, $p < 0.001$), along with optional axial 2D or 3D T2 FSE (45.6% *vs* 14.3%, $p < 0.001$). Conversely, private hospitals performed more mandatory axial T2 sequences (96.6% *vs* 88.8%, $p = 0.009$) and optional T1 SE sagittal (93.9% *vs* 81.0%, $p < 0.001$) and T1 SE axial gadolinium sequences (77.6% *vs* 53.8%, $p < 0.001$).

In report content, public hospitals significantly outperformed private settings in mentioning magnetic field strength (24.7% *vs* 8.2%, $p < 0.001$), indicating the availability of previous scans (81.5% *vs* 67.3%, $p < 0.001$), and conducting comparison studies (85.2% *vs* 61.5%, $p < 0.001$). Public hospitals also reported lesion number (54.4% *vs* 25.1%, $p < 0.001$), brain atrophy (41.8% *vs* 28.0%, $p < 0.001$), and incidentalomas (44.6% *vs* 36.3%, $p = 0.022$) more frequently. Private hospitals outperformed in reporting the studied anatomical area (99.4% *vs* 96.7%, $p = 0.008$), MRI acquisitions (92.9% *vs* 85.5%, $p = 0.004$), lesion location (96.5% *vs* 76.0%, $p < 0.001$), interpreting findings (77.7% *vs* 58.7%, $p < 0.001$), and indicating progression (44.2% *vs* 24.0%, $p < 0.001$).

Public hospitals had higher compliance in meeting technical criteria (59.4% *vs* 56.3%, $p = 0.003$) and imaging findings (53.9% *vs* 49.7%, $p = 0.004$), while private settings fulfilled more conclusion criteria (56.7% *vs* 41.7%, $p < 0.001$).

We used linear regression to assess whether improved communication (i.e., more complete requests) correlated with more complete reports. A higher average compliance with suggested topics in diagnostic MRI requests was significantly associated with higher compliance in imaging findings (R^2 0.03, beta 0.12, $p = 0.013$; HETTEST $p = 0.366$, VIF = 1.0) and conclusions (R^2 0.02, beta 0.15, $p = 0.04$; HETTEST $p = 0.7256$, VIF = 1.0). We also used logistic regression for the same purpose. For follow-up tests, higher compliance in MRI requests was significantly associated with full compliance in imaging findings (OR 1.04, CI 1.02 - 1.06, $p < 0.001$). When adjusting for compliance with suggested topics in follow-up MRI requests, reports from MRIs performed and reported in public institutions were less likely to fully meet all imaging description topics (OR 0.48, CI 0.24 - 0.99, $p = 0.049$).

DISCUSSION

The role of MRI in MS diagnosis, prognosis, and monitoring is undeniable. This is reflected in the evolving MS diagnostic criteria, incorporating MRI findings alongside clinical presentations, which has been helped by the discovery of new imaging biomarkers.[2-4] The MAGNIMS consensus and guidelines formed the ground rules that allowed

Table 4 – Diagnostic and follow-up MRI reports (n = 732)

	Diagnostic, yes, n (%) (n = 214)	Follow-up, yes, n (%) (n = 518)
Technique description		
Magnetic field strength	27 (12.6%)	94 (18.1%)
Anatomic coverage	210 (98.1%)	507 (98.1%)
MR sequences and planes acquired	198 (92.6%)	455 (87.8%)
Gadolinium-based agente	176 (82.2%)	459 (88.6%)
Gadolinium-based agent dose	1 (0.5%)	6 (1.2%)
Availability and date of a previous test	21 (53%)	388 (75.9%)
All suggested technique topics mentioned	1 (0.5%)	3 (0.6%)
At least 1 suggested technique topic not mentioned	213 (99.5%)	515 (99.4%)
Mean % suggested technique topics mentioned, mean (SD)	49.2% (0.1%)	61.4% (0.1%)
Imaging findings		
Number of T2 lesions	90 (42.5%)	200 (38.7%)
Anatomical distribution of T2 lesions	204 (96.3%)	393 (76.0%)
Subjective evaluation of lesion load	39 (18.6%)	166 (32.4%)
Number and anatomical distribution of gadolinium-enhancing T1 lesions and type of enhancement	190 (88.8%)	466 (90.0%)
Atrophy characterization with the use of validated clinical imaging scales	58 (27.1%)	198 (38.2%)
Incidental/non-MS related findings	90 (42.1%)	206 (39.8%)
Follow up: new T2 lesions, gadolinium-enhancing T1 lesions and increased size of previously detected MS plaques	—	379 (75.0%)
All suggested topics regarding imaging findings mentioned	7 (3.3%)	39 (7.5%)
At least 1 suggested topic regarding imaging findings not mentioned	207 (96.7%)	479 (92.5%)
Mean % suggested topics regarding imaging findings mentioned, mean (SD)	51.8% (0.2%)	51.8% (0.2%)
Conclusion		
Interpretation of findings and differential diagnosis	166 (77.6%)	333 (64.3%)
Indication if MR criteria of DIS and DIT are fulfilled according to the 2017 MS McDonald criteria	35 (17.2%)	—
Follow-up: conclude if there are imaging signs of new silent lesions or active plaques and identify potential therapeutic adverse effects	—	181 (35.2%)
All suggested conclusion topics mentioned	41 (19.2%)	165 (31.9%)
Mean % suggested conclusion topics mentioned, mean (SD)	47.0% (0.5%)	50.1% (0.4%)

DIS: dissemination in space; DIT: dissemination in time; SD: standard deviation

Table 5 – MRI examinations before and after the implementation of the recommendations

	Before consensus, yes, n (%)	After consensus, yes, n (%)	*p*-value
MRI requests			
Diagnostic MRI (n = 277)			
All suggested topics regarding diagnostic MRI requests mentioned	19 (31.7%)	41 (27.7%)	0.57Ŧ
Mean % suggested topics regarding diagnostic MRI requests mentioned, mean (SD)	65.0% (0.3%)	64.4% (0.3%)	0.89*
Follow-up MRI (n = 712)			
Description of diagnosis	10 (71.4%)	471 (94.0%)	< 0.001Ŧ
All suggested topics regarding follow-up MRI requests mentioned	0 (0.0%)	19 (3.8%)	0.46Ŧ
Mean % suggested topics regarding follow-up MRI requests mentioned, mean (SD)	52.7% (0.3%)	52.1% (0.2%)	0.92*
Neuroimaging protocols			
Brain MRI (n = 674)			
All mandatory sequences performed	52 (80.0%)	504 (82.8%)	0.58Ŧ
Mean % mandatory sequences performed, mean (SD)	96.9% (0.1%)	95.6% (0.1%)	0.45*
Spinal cord MRI (n = 315)			
All mandatory sequences performed	23 (85.2%)	163 (70.9%)	0.12Ŧ
Mean % mandatory sequences performed, mean (SD)	95.4% (0.1%)	91.6% (0.1%)	0.20*
MRI reports			
Technique description			
Magnetic field strenght	8 (10.4%)	113 (17.3%)	0.13Ŧ
Anatomic coverage	75 (97.4%)	642 (98.2%)	0.64Ŧ
MR sequences and planes acquired	71 (92.2%)	582 (88.9%)	0.010Ŧ
All suggested technique topics mentioned	1 (1.3%)	3 (0.5%)	0.34Ŧ
Mean % suggested technique topics mentioned, mean (SD)	51.7% (0.1%)	58.6% (0.4%)	< 0.001*
Imaging findings			
Number of T2 lesions	39 (50.6%)	251 (38.5%)	0.039Ŧ
Anatomical distribution of T2 lesions	74 (96.1%)	523 (80.2%)	0.002Ŧ
Subjective evaluation of lesion load	15 (19.7%)	190 (29.4%)	0.078Ŧ
Number and anatomical distribution of gadolinium-enhancing T1 lesions and type of enhancement	69 (89.6%)	587 (89.6%)	1.00Ŧ
Atrophy characterization with the use of validated clinical imaging scales	24 (31.2%)	232 (35.4%)	0.46Ŧ
Incidental/non-MS related findings	31 (40.3%)	265 (40.5%)	0.97Ŧ
Follow up: new T2 lesions, gadolinium-enhancing T1 lesions and increased size of previously detected MS plaques	11 (73.3%)	368 (75.1%)	0.88Ŧ
All suggested topics regarding imaging findings mentioned	5 (6.5%)	41 (6.3%)	0.94Ŧ
Mean % suggested topics regarding imaging findings mentioned, mean (SD)	53.7% (0.2%)	51.6% (0.2%)	0.37*
Conclusion			
Interpretation of findings and differential diagnosis	51 (66.2%)	448 (68.4%)	0.70Ŧ
Indication if MR criteria of DIS and DIT are fulfilled according to the 2017 MS McDonald criteria	8 (13.8%)	27 (18.5%)	0.42Ŧ
Follow-up: conclude if there are imaging signs of new silent lesions or active plaques and identify potential therapeutic adverse effects	6 (42.9%)	175 (35.0%)	0.54Ŧ
All suggested conclusion topics mentioned	15 (19.5%)	191 (29.2%)	0.074Ŧ
Mean % suggested conclusion topics mentioned, mean (SD)	42.2% (0.3%)	50.0% (0.4%)	0.089*

Ŧ: Pearson's chi-squared;
*: Two-sample t-test
DIS: dissemination in space; DIT: dissemination in time; SD: standard deviation

Table 6 – MRI examinations in public and private sectors (part 1 of 2)

	Public sector, yes, n (%)	Private sector, yes, n (%)	*p*-value
Neuroimaging protocols for brain MRI			
Mandatory sequences			
Axial T2	383 (98.7%)	284 (99.3%)	0.46ᵼ
Axial PD and/or T2-FLAIR	377 (97.2%)	284 (99.3%)	0.046ᵼ
Sagittal T2-FLAIR (2D or 3D)	360 (92.8%)	248 (86.7%)	0.009ᵼ
Axial T1 SE 2D + gad	355 (91.5%)	260 (90.9%)	0.79ᵼ
All mandatory sequences performed	330 (85.1%)	226 (79.0%)	0.042ᵼ
Mean % mandatory sequences performed, mean (SD)	96.2& (0.13)	95.1% (0.12)	0.28*
Optional sequences			
Axial T1 SE 2D	314 (80.9%)	178 (62.5%)	< 0.001ᵼ
3D T1-weighted sequences	243 (62.8%)	53 (18.6%)	< 0.001ᵼ
Axial DWI	367 (94.6%)	263 (92.3%)	0.23ᵼ
DIR	15 (3.9%)	2 (0.7%)	0.010ᵼ
SWI	189 (48.6%)	79 (27.7%)	< 0.001ᵼ
Neuroimaging protocols for spinal cord MRI			
Mandatory sequences			
Sagittal T2 SE or FSE	163 (96.4%)	143 (97.3%)	0.67ᵼ
Sagittal PD (acquired in dual echo) or STIR	160 (94.7%)	116 (78.9%)	< 0.001ᵼ
Axial T2 (lesion focused)	150 (88.8%)	142 (96.6%)	0.009ᵼ
Sagittal T1 SE + gad (if T2 lesions present)	153 (90.5%)	132 (89.8%)	0.83ᵼ
All mandatory sequences performed	127 (75.1%)	97 (66.4%)	0.089ᵼ
Mean % mandatory sequences performed, mean (SD)	92.6% (0.14)	90.6% (0.15)	0.22*
Optional sequences			
Sagittal T1 SE	136 (81.0%)	138 (93.9%)	< 0.001ᵼ
Axial T1 SE + gad	91 (53.8%)	114 (77.6%)	< 0.001ᵼ
Axial 2D or 3D T2 FSE (for all spinal cord)	77 (45.6%)	21 (14.3%)	< 0.001ᵼ
PSIR	2 (1.2%)	0 (0.0%)	0.19ᵼ
MRI reports			
Technique			
Magnetic field strength	93 (22.1%)	28 (9.0%)	< 0.001ᵼ
Anatomic coverage (brain or spinal cord and which segment)	407 (96.9%)	310 (99.7%)	0.007ᵼ
MR sequences and planes acquired	363 (86.2%)	289 (92.9%)	0.014ᵼ
Gadolinium-based agent	368 (87.4%)	267 (85.9%)	0.54ᵼ
Gadolinium-based agent dose	7 (1.7%)	0 (0.0%)	0.022ᵼ
Follow-up: availability and date of a previous brain and/or spinal MR test for comparison.	255 (79.7%)	154 (66.7%)	< 0.001ᵼ
All suggested technique topics mentioned	4 (1.0%)	0 (0.0%)	0.085ᵼ
At least 1 suggested technique topic not mentioned	417 (99.0%)	311 (100.0%)	0.085ᵼ
Mean % suggested technique topics mentioned, mean (SD)	59.1% (0.15)	56.2% (0.12)	0.005ᵼ

ᵼ: Pearson's chi-squared

*: Two-sample t-test

DIR: double inversion recovery sequence; DIS: dissemination in space; DIT: dissemination in time; DMT: disease modifying treatment; DWI: diffusion-weighted imaging; FLAIR: fluid attenuated inversion recovery; FSE: fast spin-echo; Gad: gadolinium; PSIR: phase-sensitive inversion recovery; PML: progressive multifocal leukoencephalopathy; SE: spin-echo; SD: standard deviation

Table 6 – MRI examinations in public and private sectors (part 2 of 2)

	Public sector, yes, n (%)	Private sector, yes, n (%)	*p*-value
Imaging findings			
Number of T2 lesions	213 (50.8%)	77 (24.8%)	< 0.001Ŧ
Anatomical distribution of T2 lesions, specifying if juxtacortical/cortical, periventricular, infratentorial or in spinal cord	323 (77.3%)	269 (86.5%)	< 0.001Ŧ
Subjective evaluation of lesion load (mild, moderate, severe)	123 (29.5%)	82 (26.8%)	0.43Ŧ
Number and anatomical distribution of gadolinium-enhancing T1 lesions and type of enhancement (ring, solid, concentric, etc.)	373 (88.6%)	283 (91.0%)	0.29Ŧ
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	176 (41.8%)	80 (25.7%)	< 0.001Ŧ
Incidental/non-MS related findings and its clinical significance	197 (46.8%)	99 (31.8%)	< 0.001Ŧ
Follow up: new T2 lesions, gadolinium -enhancing T1 lesions and increased size of previously detected MS plaques (comparison with previous scans)	260 (83.1%)	135 (59.2%)	< 0.001Ŧ
All suggested topics regarding imaging findings mentioned	31 (7.4%)	15 (4.8%)	0.16Ŧ
At least 1 suggested topic regarding imaging findings not mentioned	390 (92.6%)	296 (95.2%)	0.16Ŧ
Mean % suggested topics regarding imaging findings mentioned, mean (SD)	54.9% (0.20)	47.7% (0.20)	< 0.001*
Conclusion			
Interpret if findings are typical, atypical or not consistent with MS and, in this case, provide differential diagnosis	252 (59.9%)	247 (79.4%)	< 0.001Ŧ
Diagnostic: indicate if MR criteria of DIS and dissemination in time (DIT) are fulfilled according to the 2017 MS McDonald Criteria.	29 (24.0%)	11 (12.5%)	0.037Ŧ
Follow-up: conclude if there are imaging signs of new silent lesions or active plaques and identify potential therapeutic adverse effects (particularly, PML-IRIS).	84 (26.8%)	97 (44.7%)	< 0.001Ŧ
All suggested conclusion topics mentioned	106 (25.2%)	100 (32.2%)	0.038Ŧ
At least 1 suggested conclusion topic not mentioned	315 (74.8%)	211 (67.8%)	0.038Ŧ
Mean % suggested conclusion topics mentioned	43.3% (0.40)	57.1% (0.34)	< 0.001*

Ŧ: Pearson's chi-squared
*: Two-sample t-test
DIR: double inversion recovery sequence; DIS: dissemination in space; DIT: dissemination in time; DMT: disease modifying treatment; DWI: diffusion-weighted imaging; FLAIR: fluid attenuated inversion recovery; FSE: fast spin-echo; Gad: gadolinium; PSIR: phase-sensitive inversion recovery; PML: progressive multifocal leukoencephalopathy; SE: spin-echo; SD: standard deviation

the establishment of standardized protocols worldwide for optimal MRI use. In Portugal, the MS Study Group and the Portuguese Society of Neuroradiology published joint clinical practice recommendations and guidance for neurologists and neuroradiologists.[5,6] Given the recent review of MS diagnostic criteria and the prospect of adapting current recommendations, we sought to analyze the application of the current Portuguese consensus to assess areas for improvement.

In this study, we systematically obtained data on MRI requests and reports, to assess if daily clinical practice aligns with the recommendations. Most pwMS in our cohort were young females (66.0%) with RRMS (93.0%), reflecting the MS population, where the female-to-male ratio is approximately three to one and about 85% of pwMS present with an RRMS form.[7,8]

Most studies were conducted on time. However, nearly a third lacked an available report. The absence of MRI images and/or report could have significant consequences, such as diagnostic or treatment delays. Our study found that the need to reschedule appointments due to unavailable MRI results was frequent, while diagnostic or treatment delays were less common. Delays in diagnosis and treatment initiation are concerning, as evidence suggests they can negatively impact long-term outcomes for pwMS. This is particularly crucial between initial symptom onset and neurological assessment.[9,10] Moreover, factors related to the healthcare system, including access to MRI in adequate timing, play a major role in patient management, since the guidelines from the National Institute for Health and Clinical Excellence recommend six weeks between the appointment and completion of necessary investigation.[11] It is known that even short delays in diagnosis and treatment initiation may increase long-term disability. Apart from these implications, a new medical appointment is time consuming and could lower the quality of care.[9,10]

When requesting an MRI, physicians should mention essential clinical details, detailed above. For follow-up MRIs, treatment history and patient diagnosis are crucial to guide MRI planification and provide structure to the report.[12] In our study, less than 30% of the diagnostic and 3.7% follow-up MRIs included all the required details. Information regarding symptom onset and evolution was the least mentioned topic in baseline MRI requests, while description of current or previous disease-modifying therapies and treatment duration, PML risk and prior MRI data were frequently overlooked on follow-up requests. Clinical information improves the reporting process, namely, interpretation accuracy, clinical relevance and reporting confidence, without affecting the reporting time.[13] This may be critical for interpretation of findings, in particular the presence of imaging DIS/DIT criteria in diagnostic MRIs or evidence of disease progression during follow-up, which is supported by our results. Information provided by the clinician is also important when deciding the MRI protocol, including the use of gadolinium.[14] The development of guidelines aims to overcome this problem; however, gaps persist.

In clinical centers where special needs such as claustrophobia and additional information such as allergies or renal/hepatic impairment have a specific and mandatory checklist, there was a higher percentage of information provided. Checklists could be easy to implement, enhance efficiency of the information provided and reduce missed details.[15]

Adhering to standardized brain MRI protocols is critical for accurate MS diagnosis and monitoring, enabling effective comparisons between baseline and follow-up scans.[6] Most scans included mandatory brain MRI sequences, which is encouraging. Optional sequences such as axial DWI and axial SE T1 2D scans were commonly performed, DIR scans were less frequent. This discrepancy may be attributed to the limited availability of DIR sequences on older MRI scanners and the increased technical complexity associated with their acquisition and interpretation.[4]

The frequent use of DWI is particularly justified in surveillance of high-risk PML patients, namely those exposed to natalizumab.[6] Other advanced techniques like DIR and SWI offer advantages in characterizing MS plaques, including cortical involvement, central vein sign, and paramagnetic rim lesions. Notably, the central vein sign and paramagnetic rim lesions not only serve as indicators of disability and MS progression but also enhance diagnostic sensitivity and specificity, particularly in light of the forthcoming diagnostic criteria. However, one disadvantage is the limited feasibility of using advanced MRI techniques, particularly in settings where imaging centers are at full capacity and equipped with 1.5T scanners, as commonly observed in many Portuguese healthcare institutions. In fact, certain advanced imaging sequences, such as those requiring higher magnetic field strengths or specialized hardware, may not be fully compatible or optimized for use with 1.5T scanners.[4]

Spinal cord MRI in pwMS is essential despite its challenges.[16] Consensus guidelines provide guidance on mandatory and optional sequences for SC MRI. In our study, there was high compliance with mandatory sequences.[6] While the SE T1 sagittal sequence is commonly performed, the underuse of PSIR raises concerns about its perceived benefits – enhances lesion detection by providing improved contrast with surrounding tissue – and feasibility in clinical practice. However, its limited adoption may be attributed to practical constraints such as time, technical complexity and relevant equipment limitations.[17]

Furthermore, we assessed the precision of MRI reports, which are usually largely dependent on clinical information and should be concise and acknowledge technical description, imaging reading and interpretation. In our study, none of the reports fulfilled all the suggested parameters in the three proposed criteria. In terms of MRI technique description, while most reports adequately described anatomical coverage and MRI sequences, details regarding gadolinium dose and magnetic field strength were notably absent. The latter is significant as it influences the completeness and accuracy of MRI interpretations, as this technical aspect significantly influences diagnostic accuracy in MS assessment.[17]

Regarding imaging description, a minority of studies had all the suggested details. Neuroradiologists frequently mentioned the anatomical distribution of T2 lesions but often omitted lesion load and atrophy characterization in reports, limiting disease severity, progression, and treatment response assessments.

Mirroring the information provided by physicians, the conclusion of the report was frequently incomplete, with few addressing all the suggested topics. The least reported topics in diagnostic MRI were imaging DIS/DIT criteria, as well as evidence of disease progression in follow-up MRI scans. Incomplete conclusions hinder comprehensive understanding of MRI findings and may hamper effective clinical decision-making. Enhancing the thoroughness and consistency of MRI reports is crucial for clinicians to have the necessary information to make informed decisions.[17] Better clinical information provided by the requesting physician may aid in improving report thoroughness, as demonstrated by the correlation we showed between higher compliance in clinical information and higher compliance in reporting.

Comparing MRI scans before and after the 2020 consensus guidelines provides valuable insights into their impact on clinical practice. The increased frequency in MS phenotype information is noteworthy. However, it is concerning that there were no significant differences in neuroimaging protocols pre- and post-implementation periods. This suggests potential challenges in fully adhering to standardized protocols or in effectively implementing changes in clinical practice.[4] The increase in technical parameters reporting suggests a positive response to the consensus guidelines. Conversely, the reduction in information concerning lesion numbers and location raises concerns about the completeness of MRI reports.

Participating hospital centers have established varying protocols with private institutions, where private hospitals are contracted to perform MRI scans. We analyzed the data based on the setting where the MRI was conducted, comparing neuroimaging protocols and reports between settings, along with the timeliness of response, including whether the MRI was performed before the appointment and if the report was promptly available.

Scans conducted in public hospitals were less frequently available in time for the next appointment. However, the availability of the reports was similar in both settings. Thus, the location where the MRI was performed could influence the availability of MRI images but not reports, potentially impacting follow-up and therapeutic decisions when timely access to images is needed to make clinical decisions.

Neuroimaging protocols in private settings showed lower compliance with all mandatory brain MRI sequences, likely due to broader protocols, not adapted nor optimized for MS. Regarding reports in both settings, public hospitals notably outperformed the private sector in stating the availability of previous scans and making comparisons between them. This could be attributed to the unavailability of previous scans in private hospitals, while in public hospitals all scans conducted in public and private settings are often uploaded to public hospitals' patient records. Public hospitals also more frequently reported lesion count, brain atrophy, and incidentalomas. Conversely, private hospitals excelled in mentioning lesion location and interpreting findings, possibly due to the lack of previous scans to serve as comparison. Despite this, private reports more frequently indicated disease progression and better fulfilled recommended report conclusion criteria, including interpretation of findings, DIS/DIT criteria, and identification of new silent lesions, active plaques, or therapeutic adverse effects.

Therefore, when an MRI is performed in a public setting, one can anticipate more frequent comparisons between scans, while conclusions may be more detailed when the MRI is conducted in a private hospital.

Our findings have several limitations. One significant limitation was the lack of random sampling, as subjects were systematically selected from medical files based on availability until each center reached its target sample. This resulted from challenges in accessing full population lists and time constraints. Nevertheless, the large sample size and data uniformity may have mitigated this bias. Another limitation was restricted data access; in one center, MRI images and reports were unavailable in the hospital system, reducing participant availability from that center. Future studies should consider randomizing population to minimize biases. Additionally, the concept of a 'public setting' or 'private setting' as a whole may be limiting, as different centers may have varying guidelines and standards.

CONCLUSION

This study suggests that the Portuguese Consensus on MRI in MS has had limited impact on clinical practice, likely due to incomplete adherence by practitioners.

While public hospitals and private settings exhibit similarities in mandatory neuroimaging protocols, differences emerge in reporting practices. Despite the inherent limitations in this study, our findings emphasize the ongoing need to optimize MRI practices and strengthen communication between neurologists and neuroradiologists across healthcare settings. This is particularly relevant given the imminent adoption of new diagnostic criteria, which incorporate novel radiological markers and will demand more effective interdisciplinary communication and stricter adherence to standardized reporting protocols, ultimately contributing to improved diagnostic accuracy and patient management in multiple sclerosis. Future research endeavors should focus on addressing why national recommendations are not being followed and further refining MRI protocols and reporting standards to improve patient outcomes in MS management.

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AUTHOR CONTRIBUTIONS

RSR, DJP, JPG, LR, MS, MG, MS, JV, MJS: Study design, data analysis, critical review of the manuscript.

AC, AJM, ARC, CS, DC, FF, MS: Study design, data collection and analysis, writing and critical review of the manuscript.

All authors approved the final version to be published.

PROTECTION OF HUMANS AND ANIMALS

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association updated in October 2024.

DATA CONFIDENTIALITY

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

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AC received payment for the presentation *"Kesimpta: a Chave para Simplificar a Esclerose Múltipla"* from Novartis Farma; received support for attending meetings and/or travel from Merck, Janssen Cilag, Biogen Idec Portugal, Novartis Farma, Roche, Janssen Cilag and Sanofi.

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DJP received consulting fees from Roche; received payment or honoraria from Roche and Bristol for lectures, presentations, speakers' bureaus, manuscript writing or educational events; received support from Roche for attending meetings and/or travel; has a leadership or fiduciary role in the Neuroradiology Specialty National Board at the Portuguese Medical Association, and the Portuguese Neuroradiological Society.

MCS received payment or honoraria for lectures, presentations, speakers' bureaus, manuscript writing or educational events from Bial; received support for attending meetings and/or travel from Merck, Biogen, Angelini and Bial.

MG received consulting fees from Janssen-Cilag, Novartis Farma; received payment or honoraria for lectures, presentations, speakers' bureaus, manuscript writing or educational events from Janssen-Cilag, Novartis Farma and Biogen; received support for attending meetings and/or travel from Janssen Cilag and Novartis Farma.

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