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Article

Radiological Reporting Systems in Multiple Sclerosis

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Abstract: (1) Background: Although MRI is a well-established tool in Multiple Sclerosis (MS) diagnosis and management, neuroradiological reports often lack standardization and/or quantitative information, with possible consequences in clinical care. The aim of this study was to evaluate the impact of information provided by neuroradiological reports and different reporting systems on the clinical management of MS patients. (2) Methods: An online questionnaire was proposed to neurologists working in Italian tertiary care level MS centers. Questions assessed the impact of different MRI-derived biomarkers on clinical choices, the preferred way of receiving radiological information, and the neurologists' opinions about different reporting systems and the use of automated software in clinical practice. (3) Results: The online survey was completed by 62 neurologists. New/enlarging (100%) lesions, the global T2w/FLAIR lesion load (96.8%), and contrast-enhancing (95.2%) lesions were considered the most important biomarkers for therapeutic decision, while new/enlarging lesions (98.4%), global T2w/FLAIR lesion load (96.8%), and cerebral atrophy (90.3%) were relevant to prognostic evaluations. Almost all participants (98.4%) considered software for medical imaging quantification helpful in clinical management, mostly in relation to prognostic evaluations. (4) Conclusions: These data highlight the impact of providing accurate and reliable data in neuroradiological reports. The use of software for medical imaging quantification in MS can be helpful to standardize radiological reports and to provide useful clinical information to neurologists.

Keywords: multiple sclerosis; report; quantitative software; atrophy

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1. Introduction

Since many of the pathological events occurring in the brain of people with Multiple Sclerosis (MS) remain clinically silent in the short term, MRI plays a key role in the clinical management of MS patients. Indeed, MRI allows the detection of subtle disease activity in the brain [1], which is particularly relevant to the evaluation of treatment response, informing clinical decisions about disease-modifying treatment (DMT) [2,3]. Although MRI

protocols for MS diagnosis and follow-up are evolving toward a global harmonization [4], more efforts are still needed in terms of standardization of the neuroradiological report. Indeed, some attempts at standardization have been made [1,5], and current guidelines recommend the adoption of a quantitative report [4].

However, the content and form of neuroradiological reports in real life are highly variable across centers and strongly dependent on the neuroradiologist's expertise [6]. In this context, software for medical imaging quantification holds the potential to improve standardization, accuracy, and thereby clinical relevance of radiological reports [7].

To date, we have limited evidence about the impact that standardization of the reporting system and the implementation of quantitative measurements might have on the clinical decision-making of MS clinicians, with some scattered evidence suggesting that relevant MRI findings are more often reported in structured reports in MS with a decrease in interpretation times, especially in follow-up [8,9].

The aim of this study was therefore to evaluate the impact of information provided by different neuroradiological reporting systems on the clinical management of MS patients, also exploring the perceived relevance of software for medical imaging quantification in clinical practice.

2. Materials and Methods

Data were collected through an online anonymous questionnaire, developed on the platform EUSurvey (https://ec.europa.eu/eusurvey, accessed on 1 May 2022). The relative link was distributed to Italian board-certified neurologists working in tertiary care level MS centers (multidisciplinary centers devoted to the diagnosis and care of MS patients) from 9 May 2022 to 27 June 2022. The complete questionnaire, translated into English from its original version, is available in Supplementary Materials.

Briefly, the questionnaire, including multiple-choice questions, was structured in four parts:

(1) general information about the respondents' demographics and level of expertise;
(2) participants' opinion about the clinical relevance, in terms of therapeutic decisions and prognostic evaluation in real-life practice, of qualitative/semiquantitative/quantitative MRI-derived biomarkers (global T2w/FLAIR lesion load, new/enlarging T2w/FLAIR lesions, T1w hypointense lesions, post-gadolinium enhancing lesions and cerebral atrophy);
(3) participants' opinion about the impact of different reporting systems in the clinical practice, in terms of utility, clarity, and readability;
(4) participants' opinion about the inclusion, in a structured report, of quantitative data/automatically generated report with graphs and/or annotated images.

Results are presented with descriptive statistics.

3. Results

The main results are summarized in Tables 1–4, while the complete report for all answers is available in Supplementary Tables S1 and S2.

3.1. Respondents' Demographics and Level of Expertise

The survey was completed by 62 board-certified neurologists working in tertiary care level MS centers in northern (17/62, 27.4%), central (19/62, 30.6%), and southern Italy (26/62, 41.9%) (Figure 1). Most of the participants had more than 10 years of experience (24/62, 38.7%) (Figure 2A), with more than half of the respondents (34/62, 54.8%) evaluating, on average, more than 50 patients with suspected or confirmed MS in a month (Figure 2B).

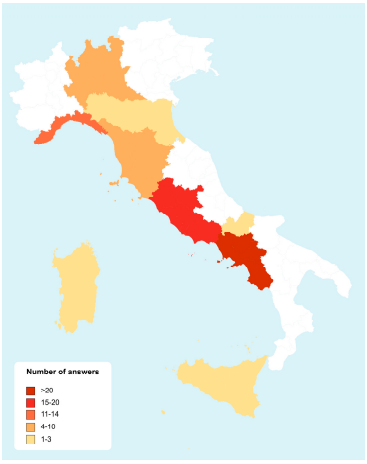

Figure 1. Geographical distribution of participants, with numbers divided by Italian regions based on their workplace.

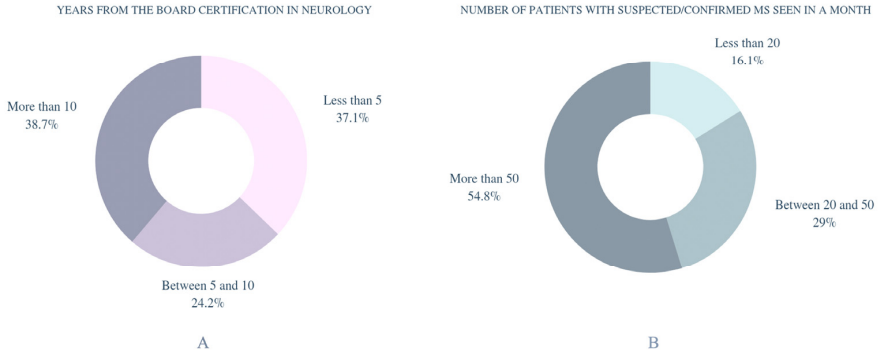

Figure 2. Pie charts showing (**A**) the years of experience of the participants, defined as the number of years from the Board Certification in Neurology, and (**B**) the average number of patients with suspected/confirmed Multiple Sclerosis usually seen in a month.

3.2. Impact of MRI-Derived Biomarkers on Therapeutic Decisions and Prognostic Evaluation

The presence of new/enlarging lesions was considered by all the neurologists (62/62, 100%) the most relevant information that can be obtained by MRI (Table 1), with the global T2w/FLAIR lesion load that resulted the most important parameter in the choice of therapy (60/62, 96.8%, with perceived importance = 4 on a scale from 0 to 5) while information about enhancing lesions (59/62, 95.2%) were considered the key feature for treatment modification (56/62, 90.3%, with perceived importance = 4 on a scale from 0 to 5). Moving from therapeutic to prognostic evaluation, new/enlarging lesions (61/62, 98.4%) and global T2w/FLAIR lesion load (60/62, 96.8%) were considered the most relevant features, followed by information about cerebral atrophy (56/62, 90.3%) and black holes (53/62, 85.5%). Information on T2w/FLAIR lesion load separated by "macro-areas" (i.e., juxtacortical, periventricular, infratentorial, spinal) proved to be of interest to the clinicians, with particular reference to lesions affecting the infratentorial (59/62, 95.2%, perceived importance = 4 on a scale from 0 to 5) and spinal cord areas (59/62, 95.2%, perceived importance = 5 on a scale from 0 to 5). The preferred presentation, within the report, for all biomarkers was the quantitative modality, without a clear preference between the range or the exact number of lesions, with the only exception being enhancing (51/62, 82.3%) and new/enlarging (37/62, 59.7%) lesions, where the exact number of lesions was preferred.

The assessment of cerebral atrophy with software for medical imaging quantification was deemed as highly relevant (46/62, 74.2%), mainly when the information was expressed as percentile norms (33/62, 53.2%), with an impact on therapeutic choices (47/62, 75.8%) but mostly on prognostic (56/62, 90.3%) evaluation (Table 2). The participants expressed a preference (44/62, 71%) for receiving information on atrophy for specific brain "macro-areas" (e.g., frontal, parietal, or deep gray matter atrophy, total gray matter volume, cortical gray matter volume, etc.) rather than global brain atrophy (22/62, 35.5%).

Table 1. Impact of lesion metrics on therapeutic and prognostic decisions.

	Global T2w/FLAIR Lesion Load		New or Enlarging T2w/FLAIR Lesions		T1w Hypointensities ("Black Holes")		Enhancing Lesions	
Answers	**Number of Answers (Percentages)**	**Median Value (Range)**	**Number of Answers (Percentages)**	**Median Value (Range)**	**Number of Answers (Percentages)**	**Median Value (Range)**	**Number of Answers (Percentages)**	**Median Value (Range)**
How would you prefer to find this information in a radiological report?								
Purely descriptive	**10 (16.1%)**		**8 (12.9%)**		**15 (24.2%)**		**8 (12.9%)**	
Lesion range	**22 (35.5%)**		**17 (27.4%)**		**25 (40.3%)**		**n.a.**	
Lesion number	**18 (29.0%)**	**n.a.**	**37 (59.7%)**	**n.a.**	**14 (22.6%)**	**n.a.**	**51 (82.3%)**	**n.a.**
Lesion volume in mL	**11 (17.7%)**		**0 (0.0%)**		**7 (11.3%)**		**3 (4.8%)**	
Other	**1 (1.6%)**		**0 (0.0%)**		**0 (0.0%)**		**n.a.**	
Does this information influence your therapeutic decisions?								
Yes	**48 (77.4%)**		**62 (100.0%)**		**38 (61.3%)**		**59 (95.2%)**	
Yes, but only in case of new diagnoses	**13 (21.0%)**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**
No	**1 (1.6%)**		**0 (0.0%)**		**24 (38.7%)**		**3 (4.8%)**	
If yes: ***Please rate how much each of these aspects of therapeutic management is affected***								
Starting a therapy	**58 (95.1%)**	**4 (1–5)**	**57 (91.9%)**	**4 (2–5)**	**33 (53.2%)**	**4 (1–5)**	**55 (88.7%)**	**4 (2–5)**
Choosing the type of therapy	**60 (98.4%)**	**4 (2–5)**	**59 (95.2%)**	**4 (3–5)**	**35 (56.3%)**	**4 (2–5)**	**55 (88.7%)**	**4 (2–5)**
Modifying the current therapy	**59 (96.7%)**	**4 (1–5)**	**59 (95.2%)**	**4 (3–5)**	**33 (53.2%)**	**4 (1–5)**	**56 (90.3%)**	**4 (3–5)**
Which of the following ways of presenting this information would be more useful to you?								
Qualitative evaluation	**7 (11.5%)**		**9 (14.5%)**		**8 (21.1%)**		**6 (10.3%)**	
Semiquantitative evaluation (lesion range)	**16 (26.2%)**		**6 (9.7%)**		**9 (23.7%)**		**n.a.**	
Quantitative evaluation (lesion number)	**25 (41.0%)**	**n.a.**	**33 (53.2%)**	**n.a.**	**13 (34.2%)**	**n.a.**	**42 (72.4%)**	**n.a.**
Quantitative evaluation (lesion volume)	**11 (18.0%)**		**14 (22.6%)**		**8 (21.1%)**		**10 (17.2%)**	
Indifferent	**2 (3.3%)**		**0 (0.0%)**		**0 (0.0%)**		**0 (0.0%)**	
Does this information influence your prognostic evaluation?								
Yes	**60 (96.8%)**	**n.a.**	**61 (98.4%)**	**n.a.**	**53 (85.5%)**	**n.a.**	**48 (77.4%)**	**n.a.**
No	**2 (3.2%)**		**1 (1.6%)**		**9 (14.5%)**		**14 (22.6%)**	
If yes: ***Which of the following ways of presenting information would be more useful to you?***								
Qualitative evaluation	6 (10.0%)		8 (13.1%)		12 (22.6%)		5 (10.6%)	
Semiquantitative evaluation (lesion range)	16 (26.7%)		7 (11.5%)		14 (26.4%)		n.a.	
Quantitative evaluation (lesion number)	21 (35.0%)	n.a.	30 (49.2%)	n.a.	17 (31.1%)	n.a.	33 (70.2%)	n.a.
Quantitative evaluation (lesion volume)	16 (26.7%)		14 (23.0%)		10 (18.9%)		9 (19.1%)	
Indifferent	1 (1.7%)		2 (3.3%)		0 (0.0%)		0 (0.0%)	

Table 1. *Cont.*

Answers	Global T2w/FLAIR Lesion Load		New or Enlarging T2w/FLAIR Lesions		T1w Hypointensities ("Black Holes")		Enhancing Lesions	
	Number of Answers (Percentages)	Median Value (Range)	Number of Answers (Percentages)	Median Value (Range)	Number of Answers (Percentages)	Median Value (Range)	Number of Answers (Percentages)	Median Value (Range)
How much would you like information about T2w/FLAIR lesion load to be separated by "macro-areas"?								
Juxtacortical	59 (95.2%)	4 (1–5)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Periventricular	57 (91.9%)	4 (1–5)						
Infratentorial	59 (95.2%)	4 (3–5)						
Spinal	59 (95.2%)	5 (3–5)						

Table 2. Impact of cerebral atrophy on therapeutic and prognostic decisions.

Answers	Number of Answers (Percentages)	Median Value (Range)
How would you prefer to find this information in a radiological report?		
Qualitative evaluation	8 (12.9%)	n.a.
Evaluation with semi-quantitative scale	8 (12.9%)	
Evaluation with quantitative software (ml of volume)	13 (21.0%)	
Evaluation with quantitative software (normative percentile)	33 (53.2%)	
Other (please specify)	0 (0.0%)	
Does information about cerebral atrophy influence your decisions about therapeutic management?		
Yes	47 (75.8%)	n.a.
No	15 (24.2%)	
If yes: ***Please rate how much each of these aspects of therapeutic management is affected:***		
Starting a therapy	40 (64.5%)	4 (1–5)
Choosing the type of therapy	41 (66.2%)	4 (2–5)
Modifying the current therapy	41 (66.2%)	4 (2–5)
Which of the following ways of presenting this information would be more useful to you?		
Qualitative evaluation	6 (12.8%)	n.a.
Semiquantitative evaluation (semi-quantitative scale)	8 (17.0%)	
Quantitative evaluation (quantitative software)	33 (70.2%)	
Indifferent	0 (0.0%)	
Does information about cerebral atrophy influence your prognostic evaluation?		
Yes	56 (90.3%)	n.a.
No	6 (9.7%)	
If yes: ***Which of the following ways of presenting information would be more useful to you?***		
Qualitative evaluation	5 (8.9%)	n.a.
Semiquantitative evaluation (semi-quantitative scale)	12 (21.4%)	
Quantitative evaluation (quantitative software)	38 (67.9%)	
Indifferent	1 (1.8%)	
Which information would you prefer to find in a radiological report? (Select one or more)		
Global atrophy	22 (35.5%)	n.a.
Atrophy of "macro-areas" of the brain	44 (71.0%)	

3.3. Reporting Systems

Respondents expressed their appreciation for the presence of a "Conclusions" section at the end of the MRI report (Table 3). In their experience, such a section is frequently present (45/62, 72.6%) and, for most people (38/62, 84.5%), represents a helpful tool in clarifying the report and/or in adding information relevant to the patients' management. Although clinicians reported a similar average reading time for descriptive and qualitative reports, with an overall similar perceived quality, the revision of MRI images occurs more frequently after reading a descriptive report (53/61, 86.9%) than a structured one (8/61, 13.1%).

Table 3. Reporting systems.

Answers	Number of Answers (Percentages)
Conclusions in the report	
In your clinical practice, do you usually find a section with "conclusions" at the end of MRI reports?	
Yes	45 (72.6%)
No	17 (27.4%)

Table 3. *Cont.*

Answers	Number of Answers (Percentages)
If this section is present:	
It clarifies the report	22 (48.9%)
It reduces my reading time	17 (37.8%)
It adds helpful information in patients' management	16 (35.6%)
It is not helpful	1 (2.2%)
Other (please specify)	0 (0.0%)
Practical implications and clinical impact of descriptive/structured reports	
Average time spent to read a descriptive report:	
<2 min	25 (40.3%)
2–5 min	30 (48.4%)
5–10 min	7 (11.3%)
>10 min	0 (0.0%)
I do not usually see these reports	0 (0.0%)
Average time spent to read a structured report:	
<2 min	25 (40.3%)
2–5 min	27 (43.5%)
5–10 min	7 (11.3%)
>10 min	0 (0.0%)
I do not usually see these reports	3 (4.8%)
After reading a descriptive report, do you usually review MR images before taking decisions about the management of MS patients?	
Yes, always	47 (75.8%)
Yes, often	14 (22.6%)
Yes, rarely	1 (1.6%)
No, I do not	0 (0.0%)
If you answered yes, please specify:	
I review MR images only if the report lacks necessary information	5 (8.1%)
I always review MR images, regardless of the quality/type of report	57 (91.9%)
Other (please specify)	0 (0.0%)
After reading structured reports, do you usually review MR images before taking decisions about the management of MS patients?	
Yes, always	40 (64.5%)
Yes, often	14 (22.6%)
Yes, but rarely	7 (11.3%)
No	1 (1.6%)
If you answered yes, please specify:	
I review MR images only if the report lacks necessary information	8 (13.1%)
I always review MR images, regardless of the quality/type of report	53 (86.9%)
Other (please specify)	0 (0.0%)
When do you find the review of MR images more useful?	
After reading a descriptive report	53 (86.9%)
After reading a structured report	8 (13.1%)
In your opinion, a structured report is more informative than a descriptive one in relation to which parameters?	
Global T2w/FLAIR lesion load	30 (53.6%)
New or enlarging T2w/FLAIR lesions	41 (73.2%)
T1w hypointensities ("black holes")	21 (37.5%)
Infratentorial lesions	26 (46.4%)
Cerebral atrophy	29 (51.8%)
Enhancing lesions	23 (41.1%)
Conclusions	13 (23.2%)
None of the above	6 (9.7%)

Table 3. *Cont.*

Answers	Number of Answers (Percentages)
Is there any information that you do not usually see in a report but that you think it would be useful for your clinical management?	
Yes	30 (48.4%)
No	32 (51.6%)
The average quality of the descriptive reports you usually see in your clinical practice is:	
Excellent	4 (7.5%)
Good	10 (18.9%)
Average	22 (41.5%)
Poor	14 (26.4%)
Insufficient	3 (5.7%)
I do not usually see these reports	1 (1.6%)
The average quality of the structured reports you usually see in your clinical practice is:	
Excellent	3 (17.6%)
Good	4 (23.5%)
Average	9 (52.9%)
Poor	1 (5.9%)
Insufficient	0 (0.0%)
I do not usually see these reports	42 (67.7%)
Which type of report is easier to understand?	
Descriptive report	15 (24.2%)
Structured report	47 (75.8%)
Which type of report is more informative for the clinical management of the patient?	
Descriptive report	7 (11.3%)
Structured report	55 (88.7%)
Which of these findings affect your decisions regarding the patient management?	
Global T2w/FLAIR lesion load	23 (37.1%)
New or enlarging T2w/FLAIR lesions	53 (85.5%)
T1w hypointensities (“black holes”)	12 (19.4%)
Infratentorial lesions	22 (35.5%)
Cerebral atrophy	19 (30.6%)
Enhancing lesions	41 (66.1%)
Conclusions	2 (3.2%)

3.4. The Role of Software for Medical Imaging Quantification

Almost all participants (61/62, 98.4%) considered software for medical imaging quantification helpful for the clinical management of MS patients (Table 4), with particular reference to prognosis (52/62, 83.9%) and the decision to start/switch a DMT (46/62, 74.2%). Among the different information usually provided by software for medical imaging quantification, 85.5% of participants (53/62) considered data about brain atrophy to be relevant for their clinical practice, alone or in combination with lesion volume. Finally, 95.2% of participants (59/62) believed that the integration of software-derived quantitative information in neuroradiological reports could reduce variability in reporting, possibly helping in standardizing descriptive reports.

Table 4. Practical implications and clinical impact of software for medical imaging quantification.

Answers	Number of Answers (Percentages)	Median Value (Range)
Did you know that quantitative volumetric reporting tools are available for MS?		
Yes	49 (79.0%)	n.a.
No	13 (21.0%)	

Table 4. *Cont.*

Answers	Number of Answers (Percentages)	Median Value (Range)
Do you think that finding this type of information in a structured report could be helpful in the management of MS patients?		
Yes	61 (98.4%)	n.a.
No	1 (1.6%)	
If yes: *Which aspect would be more affected?*		
Prognostic evaluation	52 (83.9%)	n.a.
Choice of therapy	0 (0.0%)	
Start/switch of therapy	46 (74.2%)	
Start/switch of symptomatic drug therapy	12 (19.4%)	
Start/switch of rehabilitation therapy	10 (16.1%)	
Other (follow-up)	1 (1.6%)	
These tools provide different quantitative information. Which of the following do you think could be most helpful in the clinical management of MS patients, compared with a structured report?		
T2w/FLAIR lesion load	33 (53.2%)	n.a.
T1w hypointensities ("black holes") volume	29 (46.8%)	
Enhancing lesions volume	14 (22.6%)	
Whole brain volume and normative percentile	43 (69.4%)	
Gray matter volume and normative percentile	34 (54.8%)	
White matter volume and normative percentile	19 (30.6%)	
Cortical gray matter volume (by cerebral lobe)	16 (25.8%)	
Regional T2w/FLAIR lesion load volume	25 (40.3%)	
Do you think that finding graphs that summarize this quantitative information in a report could be helpful in your clinical practice?		
Yes	59 (95.2%)	4 (2–5)
No	3 (4.8%)	
Do you think that finding annotated images that summarize this quantitative information in a report could be helpful in your clinical practice with MS patients?		
Yes	54 (87.1%)	4 (2–5)
No	8 (12.9%)	
Do you think that having some or all this information might have an impact on your clinical management of MS patients?		
Yes, I think that it would help me manage MS patients better	57 (91.9%)	n.a.
No, I think that these tools have only research applications	5 (8.1%)	
Which of the following do you perceive as more reliable?		
A radiologist writing a report without quantitative tools	0 (0.0%)	n.a.
A radiologist writing a report containing only information obtained by a quantitative tool	4 (6.5%)	
A radiologist writing a report containing some information obtained by a quantitative tool, integrated by her/his experience	58 (93.5%)	
Do you think that the integration of quantitative information processed by a software in radiological reports could reduce variability in reporting and/or can help standardize descriptive reports as well?		
Yes	59 (95.2%)	4 (3–5)
No	3 (4.8%)	

4. Discussion

Effective communication between neuroradiologists and neurologists is crucial in clinical practice, with direct repercussions on healthcare quality. In this study, we evaluated for the first time the impact of the content and structure of neuroradiological reports on the clinical choices of neurologists specialized in MS care. Clinicians were asked not only their opinion on conventional MRI biomarkers but also on the clinical significance of software-derived quantitative information, so far used almost uniquely in research settings. Our results suggest that including accurate quantitative information in neuroradiological

reports is highly relevant to clinicians. Furthermore, the use of software for medical imaging quantification in radiological assessment of MS patients is considered helpful not only to standardize radiological reports but also to inform neurologists' clinical decision-making, a result expected given the increasing use of this software but to date not available in the literature.

With reference to conventional MRI findings usually present in neuroradiological reports, our results highlight that, while some MRI biomarkers mainly affect therapeutic decisions, others are more relevant to prognostic evaluations. In particular, information about the inflammatory component of the disease, such as new/enlarging T2w/FLAIR and enhancing lesions, affects clinicians' therapeutic decisions. On the other hand, information related to the degenerative component of MS, such as cerebral atrophy or T1w black holes, mainly affects prognostic evaluations in clinical practice, though in the future could be also associated with treatment decisions. This result is somehow expected, as current immunomodulatory therapies mainly act on the inflammatory component of MS, reducing the frequency and severity of demyelinating events, with a very limited effect on the progressive neurodegenerative features of the disease [10]. Interestingly, the only MRI feature considered useful by all participants was the presence of new/enlarging lesions, which proved to be not only important in terms of therapeutic decisions (conditioning in equal measure the decision to start a new therapy, its type and eventual switches), but also in terms of prognostic assessments. In both cases, the exact number of lesions was preferred compared to a range or even more quantitative information, such as lesion volume expressed in milliliters. This result leads to some considerations, the first one being that the information about enhancing lesions seems to have a less crucial role in driving therapeutic decisions than the one historically attained. This is in line with the most recent literature, as highlighted by the recent MAGNIMS-CMSC-NAIMS consensus guidelines, in which information about new/enlarging lesions has been suggested as a reliable marker of active inflammatory disease, even superior to enhancing lesions in some clinical situations, ultimately leading to a reduction of the use of gadolinium-based contrast agents which are now not recommended in routine follow-up [4]. The second consideration is that new/enlarging T2w lesions emerged as the most important MRI feature relative to prognostic evaluations, with a preference for the exact number of lesions, proving the importance of this parameter for neurologists, as confirmed by its introduction in the definition of "minimal evidence of disease activity" (MEDA), which identifies patients at very low risk of disability accumulation [11].

A possible explanation could be found in the clinical relevance of slowly expanding lesions, reflecting a silent inflammatory progression, due to slow-burning inflammation with macrophage/microglia activation and remyelination failure with axonal loss in a context of intact blood-brain barrier [12–14]. These lesions, known to be better predictors of clinical progression compared to acute ones [15–18], seem to play a central role in the development of brain atrophy [19], confirming the interest of neurologists in identifying features related to the neurodegenerative component of MS. In this light, atrophy also emerged as another crucial information required by clinicians in neuroradiological reports, with participants preferring software-derived quantitative information to qualitative or semiquantitative estimations. Indeed, among all the possible information that can be provided by the several available software for medical imaging quantification (including, but not limited, to total lesion volume, new lesion volume, cerebral volumes, etc.), many participants showed interest in receiving information on brain atrophy (alone or in combination with lesion load), with a preference for volumetric data referred to percentile norms. These results, lining up with the wide knowledge of the role of atrophy as one of the main predictors of disability in MS [20–22], confirm the perceived clinical relevance of this information to neurologists. Although evidence that this measure might have consequences in terms of monitoring individual disease progression and treatment decision-making is still limited, this result further suggests that atrophy should be considered in the future implementation and standardization of neuroradiological reports. In addition, participants expressed a

preference for receiving information on brain "macro-areas" rather than on global volume loss. This is not unexpected, given that grey matter atrophy is not uniform in MS [23,24], with some brain regions becoming atrophic earlier than others [25–27] and impacting the accumulation of disability to different extents. In particular, thalamic atrophy is a well-recognized marker of disease progression and an early predictor of clinical disability [28], along with volume loss of the spinal cord [29–34], and the cerebellum [35–38].

When asked about the type of reporting, participants expressed a slight preference for a structured report over a descriptive one. Nevertheless, they reported the need for re-evaluating MR images more often in the presence of a descriptive report. This is also an expected result, given the larger and more comprehensive amount of information usually contained in a structured report, which is often based on templates following the MAGNIMS-CMSC-NAIMS consensus guidelines [4], therefore reducing the need for clinicians to re-evaluate images.

In the context of the increasing need for precise and accurate data, software for medical imaging quantification offers a more precise assessment of the degree of brain atrophy, comparing it with reference values as well as with data obtained from the same patient over time. Additionally, most of the participants thought that finding graphs and/or annotated images summarizing quantitative information could be helpful in their clinical practice. The main concern regarding the integration of automated software in clinical practice, along with difficulties of implementing automated tools in clinical practice, such as costs, robustness, and availability, is the lack of clinical validation [39]. Indeed, as shown by a recent meta-analysis conducted in the field of dementia [40], only less than 25% of the evaluated software tools proved to have some sort of clinical validation, with expected large variation in available quantitative reporting features coupled with a lack of comparative validation on standardized imaging cohort data. Nevertheless, the results presented here show the clinicians' interest in the translation of these tools into clinical practice, warranting future efforts to fill the gap of missing clinical validation.

The main limitation of this study is the generalizability of the study results, given the recruitment of clinicians from a single country, which might lead to a bias related to country-specific healthcare organizations. Further collaborative, international studies are warranted to expand our results, including a larger and more representative group of MS neurologists. In conclusion, our results confirm the need for standardization of neuroradiological reports among centers, given the neurologists' demand for quantitative and reliable information from brain MRI, with a direct impact on both prognosis and therapeutic decisions, with the final goal of increasing the quality of patients' care.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14135626/s1, Table S1: Key features evaluated via brain MRI in MS patients; Table S2: Reporting systems and quantification software tools.

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