LETTER TO THE EDITOR

Aggressive multiple sclerosis: a matter of measurement and timing

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We read with great interest the recently published work of Malpas et al. (2020) in which the authors identified clinical markers of patients with aggressive multiple sclerosis in a cohort of relapsing remitting multiple sclerosis (RRMS) patients with 10 years of follow-up. The authors followed the definition a confirmed Expanded Disability Status Scale (EDSS) score \( \geq 6.0 \) within 10 years of disease onset, which was initially applied by Tintore et al. (2019) to a cohort of patients with clinically isolated syndrome. In two independent databases, MSBase (2403 cases) and the Swedish MS Registry (556 cases), the authors confirmed a similar proportion of aggressive multiple sclerosis of \( \approx 6\% \). Predictors for aggressive multiple sclerosis were age at onset \( \geq 35 \) years, an EDSS of \( \geq 3.0 \) and pyramidal symptoms within the first year.

We tried to replicate the results of Malpas et al. within the data of the German MS Registry (GMSR), a nationwide registry including > 30,000 patients (with at least one follow-up since 2014) recruited from all sectors of care in over 190 centres.

By applying an interval-censored proportional hazards model, the estimated overall rate of aggressive multiple sclerosis in our GMSR cohort was 8.9% for all patients (including progressive cases; \( n = 17071 \); Fig. 1) and 7.0% if only including patients with relapsing course at onset, which is similar to previous studies. In univariate analysis of baseline covariates, age at onset [per 10 years with a hazard ratio (HR) of 2.02 and 95% confidence interval (CI) (1.91–2.14), \( P < 0.001 \)], the first year EDSS [per EDSS; HR: 3.45 (2.74–4.33), \( P < 0.001 \)] and pyramidal symptoms within the first year [HR: 4.51 (3.75–5.43), \( P < 0.001 \)] were associated with aggressive multiple sclerosis in RRMS. In multivariable analyses, however, only the EDSS after the first year and age at onset remained to be statistically significant for predicting an unfavourable course of multiple sclerosis.

Our data overall support the analysis of Malpas et al. and similar results were obtained when progressive patients were included. The progressive course per se had been identified as a risk factor for aggressive multiple sclerosis and affected patients should not be excluded unless specifically investigating forms of aggressive relapsing remitting multiple sclerosis (ARMS) (Iacobaeus et al., 2020). The ECTRIMS Focused Workshop Group further points out that a plethora of definitions of aggressive multiple sclerosis exist and there is no generally accepted definition in the literature.

We have therefore carried out further analyses of GMSR data, comparing the results for different published aggressive multiple sclerosis or highly active multiple sclerosis
definitions (Gholipour et al., 2011; Freedman and Rush, 2016; Menon et al., 2017; Diaz et al., 2019; Tintore et al., 2019; Malpas et al., 2020; Spelman et al., 2020). These definitions vary, in part considerably, regarding the parameters to be evaluated (in addition to EDSS, also relapses, MRI data, therapy response and the follow-up time needed):

(i) Freedman and Rush (2016)/Diaz et al. (2019) (fulfilment of at least one criterion within first 5 years of multiple sclerosis): $\geq 2$ relapses with incomplete recovery within 12 months; $\geq 2$ MRI with new or enlarging T2 lesions or gadolinium enhancing (GD+) lesions during 12 months on DMT; no treatment effect during first year of DMT; and confirmed EDSS $\geq 4.0$ after 5 years of disease onset.

(ii) Gholipour et al. (2011)/Menon et al. (2017): confirmed EDSS $\geq 6.0$ after 5 years of symptom onset.

(iii) Spelman et al. (2020) [highly active (HA) multiple sclerosis; we considered fulfilment any HAMS indication within first 5 years as aggressive multiple sclerosis comparator]: $\geq 2$ relapses within 12 months; $\geq 1$ GD+ lesion(s); and $\geq 9$ T2 lesions (not used since $\geq 9/\leq 9$ T2 not assessable).

(iv) Tintore et al. (2019)/Malpas et al. (2020): confirmed EDSS $\geq 6.0$ within 10 years of symptom onset; and RRMS: as a study inclusion criterion, not part of the aggressive multiple sclerosis definition.

Similar to Malpas et al., only some of our patients could be classified and analysed in the GMSR, since, depending on the definition, certain prerequisites regarding follow-up were required, e.g. in Freedman and Rush (2016)/Diaz et al. (2019), and Spelman et al. (2020) ($n = 752$), accurate data in the first 5 years after disease onset. For criteria based exclusively on sustained and confirmed EDSS, we considered it sufficient to observe the end of the follow-up period, which leads to different numbers of patients being analysed for each definition. The proportion of aggressive multiple sclerosis/highly active patients varies significantly between the different definitions from 4.0% to 23.1% (Table 1 and Fig. 1A).

Direct comparisons of various criteria showed that there is little overlap between some definitions. For example, only 1% of our patients met the aggressive multiple sclerosis/highly active criteria of the three definitions of Spelman et al. (2020), Freedman and Rush (2016)/Diaz et al., (2019), and Gholipour et al. (2011)/Menon et al. (2017) (Fig. 1B).

In summary, the term ‘aggressive multiple sclerosis’ or ‘highly active multiple sclerosis’ is used differently in the literature and no agreement between multiple sclerosis experts exists on the criteria. Using the term should be carefully

Figure 1 Aggressive multiple sclerosis according to various definitions. (A) Proportions of aggressive multiple sclerosis (MS) patients over time according to different definitions. In this interval-censored Cox model, the rising proportions of patients in the GMSR classified as aggressive multiple sclerosis according to the definitions of Freedman and Rush (2016), Diaz et al. (2019), Spelman et al. (2020), Gholipour et al. (2011), Menon et al. (2017), Tintore et al. (2019) and Malpas et al. (2020) (10 years) were presented depending on the disease duration from symptom onset. Additionally, the proportion of early retired patients in the first 5 years is given. (B) Venn diagram showing overlapping proportions of aggressive multiple sclerosis patients according to various definitions in the first 5 years of the disease ($n = 752$). Comparison of aggressive multiple sclerosis patients according to Freedman and Rush (2016) (F) Diaz et al. (2019), Gholipour et al. (2011) (G) Menon et al. (2017), Spelman et al. (2020) (S) and the early retired (ER) patients with aggressive multiple sclerosis.
considered, taking into account the fact that there was little overlap among the known definitions for aggressive multiple sclerosis, even when the same dataset is used. Although it may be plausible to distinguish between a (short-term) relapse and MRI-based highly active multiple sclerosis and a long-term EDSS-based aggressive multiple sclerosis, we believe that patient-relevant outcomes, such as ability to work, may sharpen the meaningfulness of the definition.

We do not doubt the ability of the definitions to identify aggressive patients, but we believe that three aspects must be distinguished. First, there is a need to identify patients with rapid progression of the disease due to risk factors at an early stage (aggressive multiple sclerosis). Second, there is a need for long-term results that validate which patients have a high degree of disability or malignant course, e.g. measured by EDSS, as in Tintore et al. (2019) and Malpas et al. (2020). Third, it is necessary to continuously assess the severity of the disease (highly active multiple sclerosis). Well-defined definitions should be developed for all of these aspects. In addition, non-clinical factors, such as early retirement, would be important to better assess and predict the patient’s status. A scoring system that includes several of the above-mentioned parameters could be helpful in predicting long-term outcomes and enabling evidence-based treatment decisions in the future.

Data availability
Anonymized data will be made available on request by any qualified investigator under the terms of the registries’ usage and access guidelines and subject to informed consent of the patients.

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The German MS Registry of the German MS Society was initiated and funded by the German MS Foundation and the German MS Society in 2001. It is operated by a not-for-profit company, the MSFP. In 2018, the MSFP received a grant from Merck and Novartis to support the extension of the registry and the implementation of EMA requirements. In 2019, Biogen and Celgene joined the multi-stakeholder funding approach to support the registry’s operation and to allow the collection and reporting of data required as part of the EMA-minimal dataset. Industry funding does not result in restrictions to publish data, nor do the funders have access to raw data or influence in the scientific conduct of the registry.

Competing interests
P.F. has received speaker’s fees and honoraria for advisory boards from Almirall, Bayer, Biogen Idec, Celgene, Genzyme, Novartis, Merck-Serono, Roche and Teva. He has participated in pharmaceutical company sponsored trials by Roche. None resulted in a conflict of interest. N.F. received travel funds for research meetings from Novartis. None resulted in a conflict of interest. K.H. has received speaking travel funds for research meetings from Novartis. None resulted in a conflict of interest. K.H. has received speaking fees, travel support, and research honoraria from Biogen, Teva, Sanofi-Genzyme, Novartis, Bayer Healthcare, Merck Serono, and Roche. None resulted in a conflict of interest. P.F. has received speaking fees, travel support, honoraria from advisory boards, and/or financial support for research activities from Bayer, Novartis, Biogen, Teva, Sanofi-Aventis/Genzyme, Merck Serono, Alexion, Chugai, MedImmune, Shire, German Research Council, Werth Stiftung of the City of Cologne, German Ministry of Education and Research, EU FP7 Framework Program, Arthur Arnstein Foundation Berlin, Guthy Jackson Charitable Foundation, and National Multiple Sclerosis of the USA. He serves as academic editor for *PLoS ONE* and associate editor for *Neurology, Neuroimmunology and Neuroinflammation*. None resulted in a conflict of interest. A.S. has received institutional research support from Biogen.

Table 1 Characteristics of patients with aggressive multiple sclerosis according to different definitions within the GMSR

|                  | Freedman and Rush (2016)/Díaz et al. (2019) First 5 years covered | Spelman et al. (2020) First 5 years covered | Gholipour et al. (2011)/Menon et al. (2017) at 5 years | Tintore et al. (2019)/Malpas et al. (2020) at 10 years | Early retirement at 5 years |
|------------------|--------------------------------------------------------------------|-------------------------------------------|----------------------------------------------------------|--------------------------------------------------------|-----------------------------|
| Patients, n      | 752                                                                | 752                                       | 4605                                                     | 3949                                                   | 4605                         |
| n with agMS      | 174                                                                | 141                                       | 185                                                      | 331                                                    | 525                          |
| Proportion with agMS, % | 23.1                                                              | 18.8                                      | 4.0                                                      | 8.4                                                    | 11.4                         |
| Female, %        | 70.7 (63.3–77.3)                                                   | 73.0 (64.9–80.2)                          | 61.6 (54.2–68.7)                                         | 58.6 (53.1–64.0)                                       | 67.4 (63.2–71.4)             |
| Progressive onset, % | 5.7 (2.8–10.3)                                                       | 0.7 (0.0–3.9)                             | 22.2 (16.4–28.8)                                         | 13.3 (9.8–17.4)                                        | 7.8 (5.7–10.4)               |
| Mean age at MS onset | 39.0 (37.1–40.8)                                                      | 33.6 (31.7–35.5)                          | 45.0 (43.3–46.7)                                         | 40.7 (39.5–41.9)                                       | 41.7 (40.8–42.5)             |
| Mean EDSS, last follow-up | 3.5 (3.2–3.8)                                                            | 2.1 (1.8–2.4)                              | 6.6 (6.5–6.7)                                            | 6.7 (6.6–6.8)                                          | 3.9 (3.8–4.1)                |
| Retired early, % at 5 years | 23.0 (17.0–30.0)                                                        | 8.5 (4.5–14.4)                             | 41.1 (33.9–48.5)                                         | 29.0 (24.2–34.2)                                       |                             |

Descriptive statistics are presented as mean (95% confidence intervals). Clopper-Pearson variants for proportions. agMS = aggressive multiple sclerosis; EDSS = Expanded Disability Status Scale; GMSR = German Multiple Sclerosis Registry; MS = multiple sclerosis.
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