Print ISSN 1110-208X
Online ISSN 2357-0016

Original article

Add Value of 3 Tesla MRI in the Evaluation of Multiple Sclerosis

Hany H. Lotfy, Mohamed M. Faheem, Ahmed D. Ahmed

Department of Radio-Diagnosis and Medical Imaging, Faculty of Medicine Benha University, Egypt.

Corresponding to: Dr. Ahmed Diaa El-Din Ahmed Department of Radio-Diagnosis and Medical Imaging, Faculty of Medicine Benha University, Egypt.

Email: ahmeddiaa.benha@yahoo.com

Received: 22 August 2021

Accepted:25 July 2022

Abstract:

Background: Multiple sclerosis (MS) is a complicated autoimmune illness with a wide range of symptoms. **The aim** of the present study was to describe the additional value of high field-strength (3 Tesla) MR imaging system in evaluation and monitoring of multiple sclerosis CNS lesions. **Methods:** This study was conducted on 25 MS patients; they were exposed to MRI protocol for multiple sclerosis with post contrast (gadolinium) injection images. Scans were performed during 2 sessions separated by 1 to 3 days on both 1.5T and 3.0 T. **Results:** The mean age of the studied patients was 30 years, the number of lesions showed significant differences between 1.5 Tesla and 3 Tesla with wider ranges of lesions was detected using 3 Tesla at these sites: periventricular (P-value = 0.005), juxta cortical (P-value = 0.01), deep white matter (P-value = 0.016), spinal cord (P-value = 0.041). No significant difference was reported at the infratentorial site (P-value = 0.054). Regarding all lesions, the mean number of lesions was significantly higher (P<0.001) using 3 Tesla (16 lesions) than 1.5 Tesla (13 lesions). Mean size of smallest lesion was significantly lower using 3 Tesla compared to 1.5 Tesla at these sites: Periventricular (P-value = 0.003), juxacortical (P-value = 0.015), deep white matter (P-value = 0.015), and spinal cord (P-value = 0.046). No significant difference was reported at infratentorial site (P-value = 0.057). **Conclusion:** 3.0 T scans are more sensitive at detecting both number and size of supratentorial demyelinating lesions when compared with a 1.5-T scanner.

Keywords: 3tesla; MRI; Multiple Sclerosis

Introduction

Multiple sclerosis (MS) is a complicated autoimmune illness with a wide range of symptoms. MS affects individuals during the most productive time of their life, and directly inhibits their work ability, resulting in substantial social and economic ramifications. The mean age at MS onset is about 26 years, with female dominance (female to male ratio is 2:1) (1).

Multiple sclerosis (MS) is the most common chronic inflammatory demyelinating disease affecting the central nervous system of young adults leading, in most cases, to severe and irreversible clinical disability. The clinical course of MS is extremely variable. In about 85% of MS cases, the patient presents with a clinically isolated syndrome involving the optic nerve, brainstem, or spinal cord (2).

Magnetic resonance (MR) imaging has high sensitivity, revealing macroscopic tissue abnormalities in patients with MS. Conventional MR sequences, such as dual-echo, fluid-attenuated inversion-recovery (FLAIR), and T1-weighted imaging, both with and without administration of a gadolinium-based contrast agent, provide important pieces of information for diagnosing MS, understanding its natural history, and assessing treatment efficacy. Dual-echo and FLAIR imaging have a high sensitivity for detection of MS lesions, which appear as focal areas of hyperintensity on these types of images. However, there is a lack of specificity to the heterogeneous pathologic substrates of individual lesions. In particular, edema, inflammation, demyelination, remyelination, gliosis, and axonal loss, all lead to a similar appearance of hyperintensity on dual-echo and FLAIR images. Gadolinium-enhanced T1-weighted MR images allow active lesions to be distinguished from inactive lesions, since enhancement occurs because of increased blood-brain barrier permeability and corresponds to areas of ongoing inflammation. Finally, lesions that persistently appear dark on pre- and postcontrast T1-weighted images (lesions also known as “black holes”) are associated with more severe tissue damage (both demyelination and axonal loss), compared with lesions that do not appear dark on T1-weighted images (3).

Magnetic resonance (MR) imaging is the most powerful preclinical tool for diagnosing and monitoring over time patients with multiple sclerosis (MS). MR imaging is particularly sensitive to the white matter (WM) disease associated with MS because WM changes affect many measurable MR imaging

parameters, including proton density, water diffusion, T1 and T2 relaxation times and cross relaxation. Changes in these parameters are interpreted as indicators of myelin and axon loss, which may follow the initial inflammatory process in MS-induced WM lesions (4).

Over the past few years, ultra-high-field-strength MR imaging systems have become available for clinical research. Owing to combined gains in image contrast and spatial resolution as compared with lower field strength systems, imaging at ultra-high fields has the potential to improve the understanding of diseases such as MS (5).

We aimed to describe the additional value of high field-strength (3 Tesla) MR imaging system in evaluation and monitoring of multiple sclerosis brain lesions.

Patients and methods

This study is a prospective descriptive study. The study was carried out in Mustafa Kamil Military Hospital, on the MS patients presented to neurology department and at the out-patient clinic in Mustafa Kamil Military Hospital during the period from May 2020 to November 2020 (estimated to be 25 patients). Patients were diagnosed According to McDonald criteria (6).

Official permissions were obtained from the dean Moustafa-Kamil Military Hospital. Official permissions were obtained from the radio -diagnosis department, Moustafa-Kamil Military Hospital. Ethical approval was obtained from both the institutional review board (IRB) of Armed Forces College of Medicine and from the ethical committee of Benha Faculty of Medicine. The study group was informed about the nature, the purpose and side effects of the study and written consent were taken.

Inclusion Criteria:

- The study was performed on patients diagnosed with multiple sclerosis according to McDonald criteria
- No age predilection.
- No gender predilection.

Exclusion Criteria:

- Patients with absolute contraindications to MRI.

All patients were subjected to complete history taking and full clinical examination by referring clinician.

Examination by (MRI): patients were exposed to MRI protocol for multiple sclerosis with post contrast (gadolinium) injection images. Scans were performed during 2 sessions separated by 1 to 3 days on both 1.5T and 3.0 T. The patients were scanned on Philips Achieva Healthcare MR systems (3T) and Philips Intera

Healthcare MR systems (1.5T). (Philips, Best, The Netherlands). On each scanner, a clinical MRI protocol was acquired, including an axial 3D FLAIR (Fluid Attenuated Inversion Recovery) sequence and a sagittal 3D T1-weighted turbo field echo sequence. This protocol was obtained twice on each scanner for all patients. Note that patients were not removed from the scanner in between the acquisition of the two MRI protocols.

Statistical analysis

Data management and statistical analysis were done using SPSS version 25. (IBM, Armonk, New York, United States). Quantitative data were assessed for normality by the Shapiro-Wilk test and direct data visualization methods. Numerical data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages. The number of lesions was compared between 1.5 Tesla and 3 Tesla using Wilcoxon signed ranks test. The size of the smallest lesions was compared using paired t-test. Restricted diffusion was compared using the McNemar test. All statistical tests were two-sided. P values less than 0.05 were considered significant.

Results

This study was conducted on 25 MS patients presented to the neurology department and outpatient clinic in Mustafa Kamil Military Hospital during the period from May 2020 to November 2020. The mean age of the studied patients was 30 years, with a standard deviation of 6 years. There was a female predominance; more than two thirds (68.0%) were females. Median EDSS was four and ranged from two to seven (table,1).

The number of lesions showed significant differences between 1.5 Tesla and 3 Tesla with wider ranges of lesions which were detected using 3 Tesla at these sites: periventricular (P-value = 0.005), juxta cortical (P-value = 0.01), deep white matter (P-value = 0.016), spinal cord (P-value = 0.041). No significant difference was reported at the infratentorial site (P-value = 0.054). Regarding all lesions, the mean number of lesions was significantly higher (P<0.001) using 3 Tesla (16 lesions) than 1.5 Tesla (13 lesions) (Table 2).

Table (1) General characteristics of the studied patients

General characteristics		
Age (years)	Mean ±SD	30 ±6
Gender	Males n (%)	8 (32.0)
	Females n (%)	17 (68.0)
EDSS	Median (range)	4 (2 – 7)

EDSS = Expanded Disability Status Scale

Table (2) Number of lesions at different sites by 1.5 Tesla and 3 Tesla

Periventricular			P value
1.5 Tesla	Median (range)	5 (2 - 7)	0.005
3 Tesla	Median (range)	5 (3 - 9)	
Juxtacortical			
1.5 Tesla	Median (range)	3 (0 - 6)	0.01
3 Tesla	Median (range)	3 (1 - 7)	
Deep white matter			
1.5 Tesla	Median (range)	3 (1 - 5)	0.016
3 Tesla	Median (range)	4 (1 - 6)	
Infra tentorial			
1.5 Tesla	Median (range)	2 (0 - 4)	0.054
3 Tesla	Median (range)	2 (0 - 5)	
Spinal cord			
1.5 Tesla	Median (range)	0 (0 - 2)	0.041
3 Tesla	Median (range)	0 (0 - 4)	
All lesions			
1.5 Tesla	Mean ±SD	13 ±3	<0.001
3 Tesla	Mean ±SD	16 ±3	

Wilcoxon signed ranks test was used for all sites. Paired t-test was used for all lesions

Mean size of the smallest lesion was significantly lower using 3 Tesla compared to 1.5 Tesla at these sites: Periventricular (P-value = 0.003), juxacortical (P-value = 0.015), deep white matter (P-value = 0.015), and spinal cord (P-value = 0.046). No significant difference was reported at infratentorial site (P-value = 0.057) (Table 3).

No significant difference was reported between 1.5 Tesla and 3 Tesla regarding restricted diffusion (P-value = 1.0). No cortical lesions were detected using 1.5 Tesla or 3 Tesla (Table 4).

Table (3) Size of smallest lesions at different sites by 1.5 Tesla and 3 Tesla

	Mean ±SD	P value
Periventricular		
1.5 Tesla	2.4 ±0.5	0.003
3 Tesla	2 ±0.7	
Juxtacortical		
1.5 Tesla	2.5 ±0.5	0.015
3 Tesla	2.1 ±0.6	
Deep white matter		
1.5 Tesla	2.4 ±0.5	0.015
3 Tesla	2.1 ±0.7	
Infra tentorial		
1.5 Tesla	2.5 ±0.5	0.057
3 Tesla	2.3 ±0.7	
Spinal cord		
1.5 Tesla	2.4 ±0.4	0.046
3 Tesla	1.9 ±0.6	

Paired t-test was used

Table (4) Restricted diffusion and cortical lesions by 1.5 Tesla and 3 Tesla

Restricted diffusion	n (%)	P value
1.5 Tesla	20 (80.0)	1.0
3 Tesla	20 (80.0)	
Cortical lesion		
1.5 Tesla	0 (0.0)	-
3 Tesla	0 (0.0)	

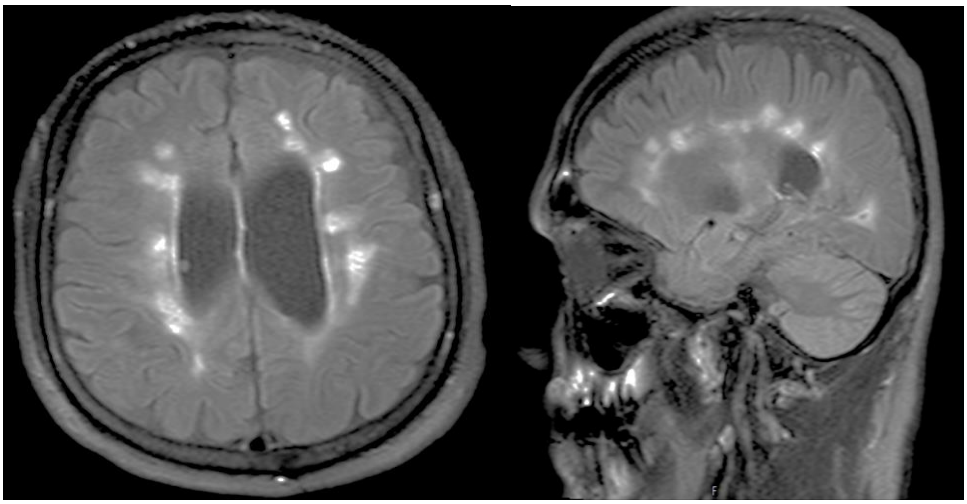
Case 1 (figure 1): Thirty-two years old male patient with known MS. Demyelinating lesions are clearly seen in FLAIR and T2WIs sequences in a periventricular distribution. There are a number of periventricular hyperintense lesions. The lesions appear more well defined with higher number in the 3T scanner images.

Case 2 (figure 2): A case of twenty-nine years old female with disease duration of 5 years. MRI shows FLAIR hyperintense periventricular lesions and can be seen on T2WIs but not clear in DWI images and

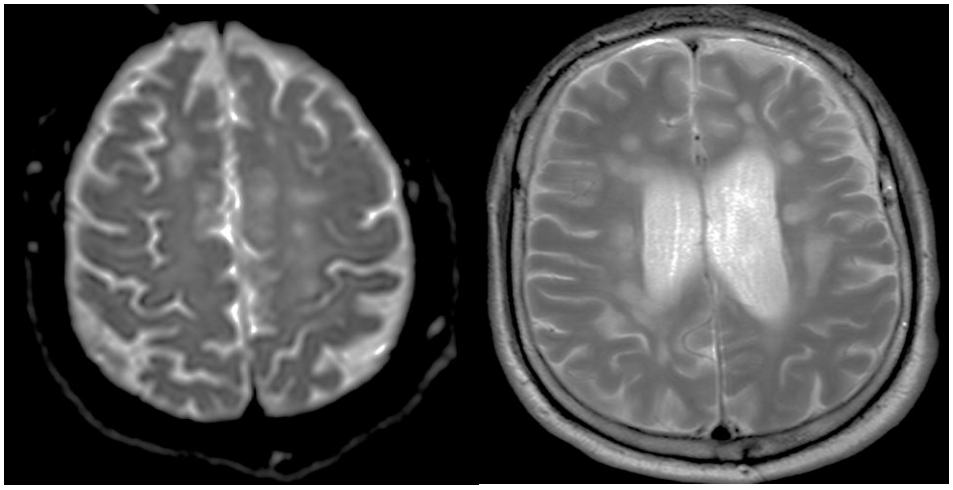
we notice especially on T2 images, the difference between 3T and 1.5 images in definition of the lesions.

Figure 1 (case 1)

Figure 1 (case 1)

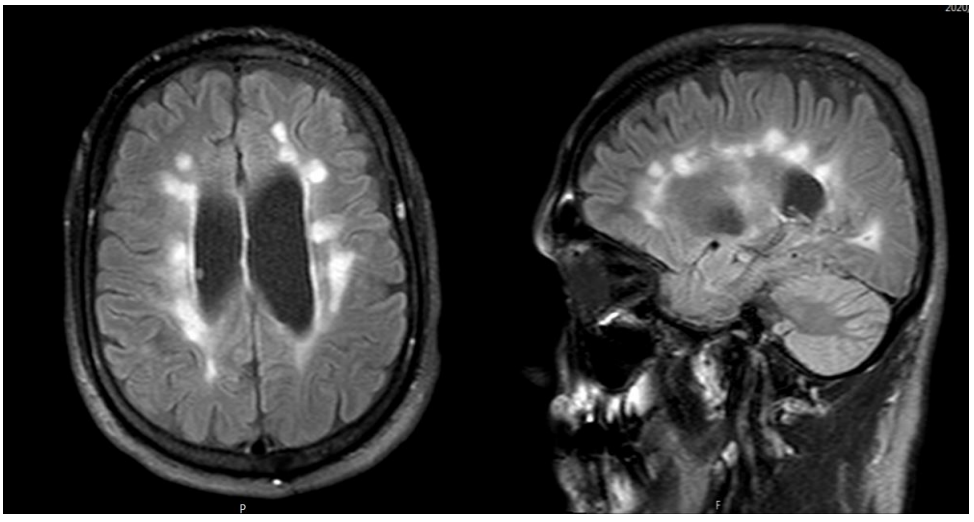


FLAIR on 1.5 T

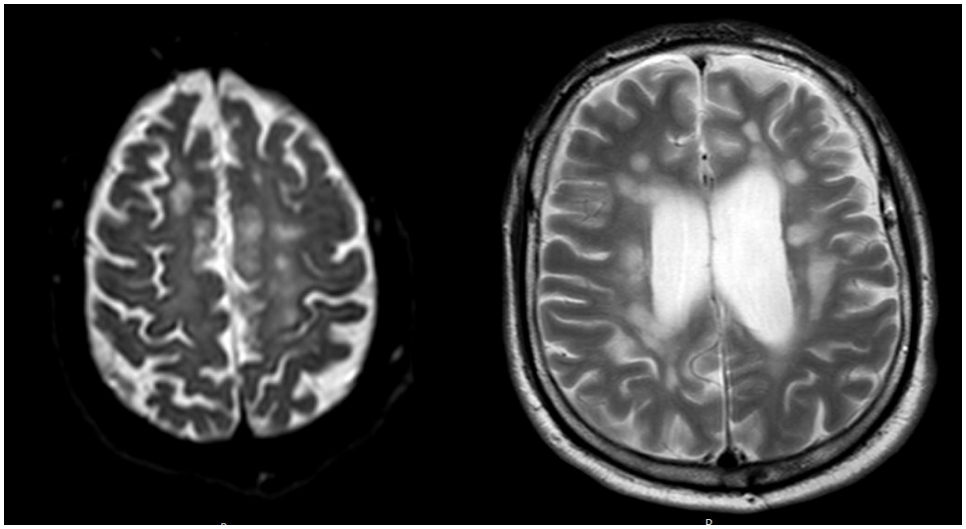


DWI on 1.5 T

T2 on 1.5 T

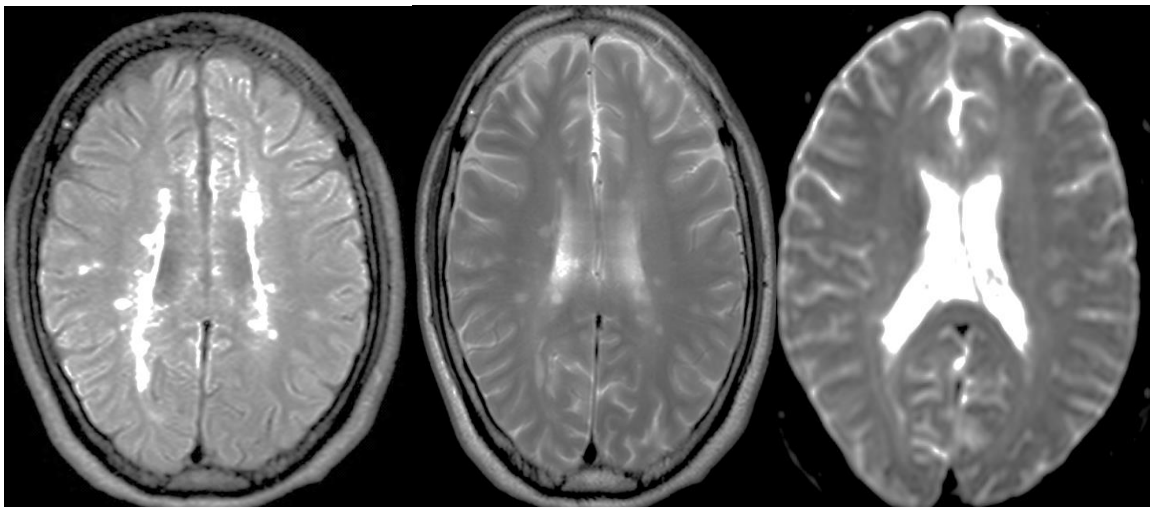


FLAIR on 3 T

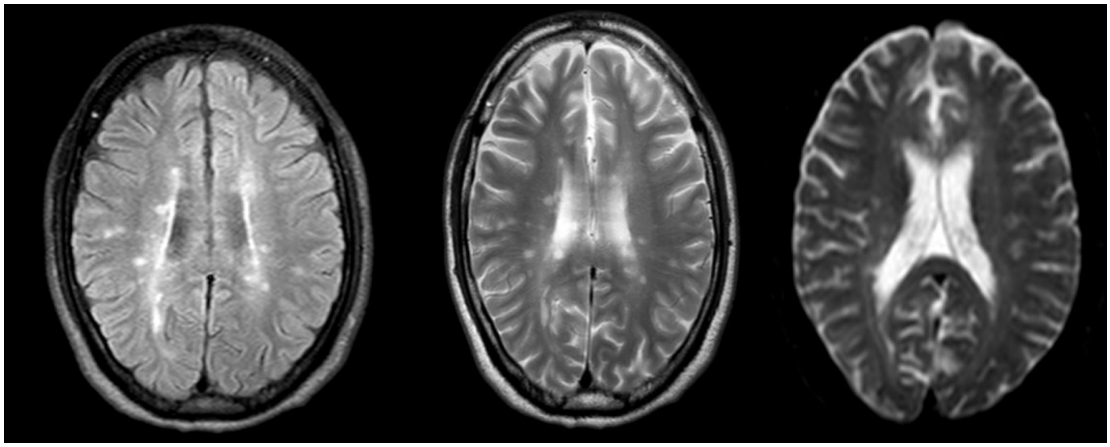


DWI on 3 T T2WIs on 3 T

Figure 2 (case 2)



FLAIRon 1.5T T2 on 1.5 T DWI on 1.5 T



FLAIRon 3T T2 on 3 T DWI on 3T

Discussion

The mean age of the patients in the current study was 30 years, with a standard deviation of 6 years. There was a female predominance; more than two thirds of the patients (68%) were females. The median of the Expanded Disability Status Scale=4 (range 2-7).

These results was close to Hagens et al. study where patients' mean age was 34.7 years, 71% were female, the median EDSS was 2.0. (7). In Tallantyre et al study, mean age was 36.6 years; range, 24–48 years; mean disease duration, 9.9 years; range, 0.25–23 years; median Expanded Disability Status Scale (EDSS) 2.5; range, 0–6.5 (8**),** while in Khangure and Khangure study which was done on 56 patients (nine male, 47 female), age range was 25-71 and median age was 42 (9).

Various MRI platforms with different magnetic field strengths are in use for the diagnosis of MS, and the most frequently applied magnet strengths are 1.5 Tesla (1.5 T) or 3 T. The latter has been shown to have increased sensitivity for the detection of MS lesions due to improved resolution and signal-to-noise ratio. However, the use of high-field 3 T MRI in comparison to 1.5 T has not been shown to improve early diagnosis of MS (10).

Despite these findings, 3 T MRI is the preferred magnet strength in the modified McDonald criteria, however both field strengths are included in the recommendations. Specific MRI sequences have been recommended by modified McDonald as the most appropriate for the diagnosis of MS. As per the guidelines, the following sequences are mandatory: axial proton density or T2-weighted/T2- fluid attenuated inversion recovery (FLAIR) spin echo or turbo spin echo, sagittal two-dimensional (2D) or three-dimensional (3D) T2-FLAIR and axial 2D or 3D post-contrast T1-weighted spin echo or turbo spin echo. Optional sequences include unenhanced 2D or high-resolution isotropic 3D T1-weighted, 2D or 3D dual inversion recovery, and axial diffusion weighted imaging (DWI) (11).

As higher field strengths improve signal-to-noise ratio, resulting in increased image quality, some expert panel guidelines recommend brain imaging at 3T MRI for diagnostic and treatment monitoring purposes.

In the present study, the number of lesions showed significant differences between 1.5 Tesla and 3 Tesla with wider ranges of lesions was detected using 3 Tesla at these sites: periventricular (P-

value = 0.005), juxta cortical (P-value = 0.01), deep white matter (P-value = 0.016), spinal cord (P-value = 0.041). No significant difference was reported at the infratentorial site (P-value = 0.054). Regarding all lesions, the mean number of lesions was significantly higher (p<0.001) using 3 Tesla (16 lesions) than 1.5 Tesla (13 lesions).

These results were in the same line with Wattjes et al.**; they detected** an increased lesion rate at 3T was seen in periventricular, (juxta) cortical, and deep white matter regions. Contrary to the previous research, in our study, 3T did not improve identification of infratentorial lesions (12).

Mean size of the smallest lesion was significantly lower using 3 Tesla compared to 1.5 Tesla at these sites: Periventricular (P-value = 0.003), juxacortical (P-value = 0.015), deep white matter (P-value = 0.015), and spinal cord (P-value = 0.046). No significant difference was reported at infratentorial site (P-value = 0.057).

The same result was reported in Wattjes et al. study. They compared 1.5 T and high-field MRI operating at 3.0 T, and found a strong influence of the higher field strength on the lesion detection rate using FLAIR, T2 regarding size (12).

In the same line with Hagens et al., study, the number of T2 lesions scored in patients at baseline was slightly but significantly higher at 3T compared to 1.5T, with a mean of 13.5 per patient at 1.5T (median 8, interquartile range [IQR] 3.0–18.5) and 15.3 at 3T (median 8, IQR 4.8–21.0) (p < 0.001). This was driven by increased lesion detection at 3T in deep white matter, periventricular, and (juxta)cortical regions, of which the first 2 reached statistical significance (7).

MS lesion characteristics in terms of lesion size and shape are not clearly defined within imaging and diagnostic criteria. However, certain anatomic locations and a distinct distribution of inflammatory white matter lesions are known to be rather specific for multiple sclerosis. Those anatomic regions including the infratentorial, juxtacortical and periventricular white matter were incorporated into imaging and diagnostic criteria (13).

Previous single-center and single-vendor studies have demonstrated that 3T MRI increases lesion detection in the brain, especially in (juxta)cortical, periventricular, and infratentorial regions, but little is known about the spinal cord (14).

MRI scans of multiple sclerosis patients, performed on both 1.5 and 3.0 T field strengths using the same pulse sequences with the same image resolution, yielded greater numbers of lesions and as well as

greater white matter lesion volumes from the higher field scanner (15).

However, we did not give the patients contrast, because it was not indicated by their treating clinician, and this is considered a limitation in our study. Instead, we used DWIs as an indicator of activity.

However, the effect of higher detection rates of the MS lesions at 3T on the establishment of the diagnosis of MS is still unclear. There might be a mild influence of high-field MRI on diagnostic criteria in terms of the lesion dissemination in space, but whether 3T MRI provides an earlier diagnosis of MS has not been investigated so far (12).

Conclusion

3.0 T scans are more sensitive at detecting both number and size of supratentorial demyelinating lesions when compared with a 1.5-T scanner. Thus, it can be more sensitive in the assessment of the dissemination of the demyelinating plaques in time and space. No difference between 3.0 T and 1.5 T scanners in assessment of the infratentorial lesions and the detection of plaques activity using DWIs.

Sources of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution

Authors contributed equally in the study**.**

Conflicts of interest

No conflicts of interest

References

1. Wootla B, Eriguchi M, Rodriguez M. Is multiple sclerosis an autoimmune disease? Autoimmune Dis. 2012;2012.

2. Nicholas JA, Electricwala B, Lee LK, Johnson KM. Burden of relapsing-remitting multiple sclerosis on workers in the US: a cross-sectional analysis of survey data. BMC Neurol. 2019;19(1):1–13.

3. Fisniku LK, Brex PA, Altmann DR, Miszkiel KA, Benton CE, Lanyon R, et al. Disability and T2 MRI lesions: a 20-year follow-up of patients with relapse onset of multiple sclerosis. Brain. 2008;131(3):808–17.

4. Gilmore CP, DeLuca GC, Bö L, Owens T, Lowe J, Esiri MM, et al. Spinal cord neuronal pathology in multiple sclerosis. Brain Pathol. 2009;19(4):642–9.

5. Hammond KE, Metcalf M, Carvajal L, Okuda DT, Srinivasan R, Vigneron D, et al. Quantitative in vivo magnetic resonance imaging of multiple sclerosis at 7 Tesla with sensitivity to iron. Ann Neurol Off J Am Neurol Assoc Child Neurol Soc. 2008;64(6):707–13.

6. Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, et al. Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. Lancet Neurol. 2018;17(2):162–73.

7. Hagens MHJ, Burggraaff J, Kilsdonk ID, de Vos ML, Cawley N, Sbardella E, et al. Three-Tesla MRI does not improve the diagnosis of multiple sclerosis: A multicenter study. Neurology. 2018;91(3):e249–57.

8. Tallantyre EC, Morgan PS, Dixon JE, Al-Radaideh A, Brookes MJ, Morris PG, et al. 3 Tesla and 7 Tesla MRI of multiple sclerosis cortical lesions. J Magn Reson Imaging. 2010;32(4):971–7.

9. Khangure SR, Khangure MS. MR imaging in multiple sclerosis: the accuracy of 3D double inversion recovery at 3 Tesla and the potential for single sequence imaging. Neuroradiol J. 2011;24(1):92–9.

10. Kaunzner UW, Gauthier SA. MRI in the assessment and monitoring of multiple sclerosis: an update on best practice. Ther Adv Neurol Disord. 2017;10(6):247–61.

11. Traboulsee A, Simon JH, Stone L, Fisher E, Jones DE, Malhotra A, et al. Revised recommendations of the consortium of MS centers task force for a standardized MRI protocol and clinical guidelines for the diagnosis and follow-up of multiple sclerosis. Am J Neuroradiol. 2016;37(3):394–401.

12. Wattjes MP, Harzheim M, Kuhl CK, Gieseke J, Schmidt S, Klotz L, et al. Does high-field MR imaging have an influence on the classification of patients with clinically isolated syndromes according to current diagnostic MR imaging criteria for multiple sclerosis? Am J Neuroradiol. 2006;27(8):1794–8.

13. Polman CH, Reingold SC, Banwell B, Clanet M, Cohen JA, Filippi M, et al. Diagnostic criteria for multiple sclerosis: 2010 revisions to the McDonald criteria. Ann Neurol. 2011;69(2):292–302.

14. Stankiewicz JM, Neema M, Alsop DC, Healy BC, Arora A, Buckle GJ, et al. Spinal cord lesions and clinical status in multiple sclerosis: A 1.5 T and 3 T MRI study. J Neurol Sci. 2009;279(1–2):99–105.

15. Bink A, Schmitt M, Gaa J, Mugler JP, Lanfermann H, Zanella FE. Detection of lesions in multiple sclerosis by 2D FLAIR and single-slab 3D FLAIR sequences at 3.0 T: initial results. Eur Radiol. 2006;16(5):1104–10.

To cite this article: Hany H. Lotfy, Mohamed M. Faheem, Ahmed D. Ahmed. Add Value of 3 Tesla MRI in the Evaluation of Multiple Sclerosis. BMFJ 2022;39(2): 730-741. DOI: 10.21608/bmfj.2022.91986.1466