MJMR, Vol. 36, No. 3, 2025, pages (26-31).

Open Access
ISSN:2682-4558

Research Article

Non-Conventional Brain MRI Techniques in Studying Patients with Multiple Sclerosis

Nadia Farouk Mohammed El-Ameen[1], Tamer El Zaeem Esmaeel[1], Muhammad Mamdouh Ismail[2] and Aya Ayman Amin [1]

[1] Department of Radiology, Faculty of Medicine; Minia University, Minia, Egypt
[2] Department of Neurology, Faculty of Medicine, Minia University, Minya, Egypt

DOI: 10.21608/MJMR.2025.397309.2001

Abstract

Background: Diffusion tensor imaging (DTI), even in the normal appearing white matter (NAWM), showed significant microstructural abnormalities in multiple sclerosis (MS) patients. Detection of central vein sign (CVS) by Susceptibility weighted imaging (SWI) improve diagnostic specificity and help in differentiating MS lesions from lesions due to other white matter disorders. The aim of this work was to determine the significance of DTI and SWI techniques in studying MS patients. **Methods:** Prospective study conducted on 12 patients with MS and 16 healthy controls, referred from neurology department to radiology department of Minia University Hospital during the timeframe from September 2024 to February 2025. Imaging was accomplished utilizing closed Ingenia Philips 1.5 Tesla MRI unit. Sequences obtained were: conventional 2D axial T1, T2 weighted images and 2D axial FLAIR. Non-conventional techniques used were DTI and SWI. **Results:** Regarding DTI, it was found that mean ± SD of fractional anisotropy (FA) at NAWM of MS patients 0.4 ± 0.03, and mean ± SD of FA at white matter of controls 0.56 ± 0.06, with statistically significant difference. Central vein sign diagnosed by SWI, was seen in 172 MS lesions out of a total no. of 363 in all studied patients, with a percent of (47.3%). All studied patients had more than 6 central vein sign lesions. **Conclusion:** DTI and SWI are non-conventional brain MRI techniques that significantly help in studying and diagnosing patients with MS.

Keywords: DTI, SWI, MS

Introduction

Multiple sclerosis (MS) usually begins in individuals at age between 20 and 50 years old. It is thought to be the most frequent cause of neurology-related disability in young people, affecting women around twice as frequently as men [(1)]. Conventional magnetic resonance imaging (MRI) techniques are typically utilized as the main method for diagnosing and monitoring patients with MS [(2)]. Diffusion tensor imaging (DTI) represents a specialized form of MRI-based neuroimaging technique that allows in vivo assessment of the organization and directionality of white matter (WM). It enables both quantitative and qualitative analyses of main WM tracts and their microstructural integrity. It demonstrates extensive alterations in the microstructural properties of tissues, defined by increased mean diffusivity (MD) and decreased fractional anisotropy (FA), indicating deterioration in white matter integrity [(3)]. DTI has shown that even the normally appearing white matter (NAWM), gray matter, optic nerves, and spinal cord, which appear normal on standard MRI scans, exhibits significant microstructural abnormalities in MS patients. Changes in DTI metrics in NAWM can correlate with clinical disability and disease progression [(4)].

Susceptibility weighted imaging (SWI) was initially referred to as BOLD (blood oxygen level dependent) venographic imaging. It is an MRI technique that is highly sensitive to blood products, calcifications and iron deposition which have unique magnetic properties [(5)]. Presence of a central vein within a lesion suggests inflammatory demyelination which is characteristic for MS. Detection of central vein sign by SWI has been shown to improve diagnostic specificity and help in differentiating MS lesions from lesions due to other white matter disorders [(6)]. The aim of this work was to determine the significance of DTI and SWI techniques in studying MS patients.

Patients & Methods

(Group 1):

This prospective study involved 12 patients with MS, all were females, referred from neurology department to radiology department of Minia University Hospital during timeframe from September 2024 to February 2025. Patients were diagnosed according to Mc Donald criteria, 2017 **(7).** We included patients who are capable to comply with the study protocol aged between 18 to 50 years old. The exclusion criteria were patients with concomitant supra or infratentorial brain lesions other than MS lesions, and those with contraindications to MRI examination such as (cardiac pacemakers, cochlear implant, neuro stimulator, claustrophobia). All patients underwent a thorough history taking and an extensive neurological examination. Imaging was accomplished utilizing closed Ingenia Philips 1.5 Tesla MRI unit with a standard head coil. The following sequences were acquired:

2D axial T1-weighted images were acquired with a repetition time (TR) of 11.0 seconds and an echo time (TE) of 600 milliseconds. The imaging protocol included a slice thickness of 5 mm, a matrix size of 512 × 512, an inter-slice gap of 1–2 mm, a flip angle of 90°, and a field of view (FOV) of 220 mm.

2D axial T2-weighted images were obtained using a repetition time (TR) of 4000 ms and an echo time (TE) of 98 ms. Imaging parameters included a slice thickness of 5 mm, one signal average (NSA = 1), a matrix resolution of 512 × 512, an inter-slice gap of 1–2 mm, a flip angle of 90°, and a field of view (FOV) of 220 mm.

2D axial FLAIR images were acquired with the following parameters: repetition time (TR) of 10,000 ms, echo time (TE) of 120 ms, slice thickness of 5 mm, number of signal averages (NSA) set to 2, a matrix size of 512 × 512, an inter-slice gap ranging from 1 to 2 mm, a flip angle of 90°, and a field of view (FOV) of 220 mm

Diffusion-weighted imaging (DWI) and Apparent Diffusion Coefficient (ADC) maps were obtained using the following parameters: repetition time (TR) of 4045 ms, echo time (TE) of 127 ms, 5 mm slice thickness, 1 mm inter-slice gap, a matrix size of 152 × 105, a flip angle of 90°, and a field of view (FOV) of 231 mm. ADC maps were processed using the standard software integrated into the imaging system. Regions of interest (ROIs) were placed centrally within each lesion to measure ADC values, which were automatically calculated and reported in units of 10^{-3} mm²/s. A threshold of 1×10^{-3} mm²/s was employed to distinguish restricted diffusion from non-restricted areas.

Diffusion tensor imaging (DTI) was acquired using a single-shot spin-echo echo-planar imaging sequence with 12 diffusion-encoding directions. The b-values used were 0, 800, and 1000 s/mm². Imaging parameters included a repetition time (TR) of 8000 ms, echo time (TE) of 67 ms, a flip angle of 90°, an acquisition matrix of 112 × 110, a field of view (FOV) of 210 × 236 mm², slice thickness of 2 mm, and two signal excitations

Susceptibility-weighted imaging (SWI) was performed using the following parameters: repetition time (TR) ranged from 25 to 50 ms, echo time (TE) between 20 and 40 ms, and flip angles from 15° to 20°. As magnetic field strength increases, shorter TR and TE values and smaller flip angles are typically applied. The imaging matrix was set at 288 × 384 × 104 with a voxel resolution of 0.65 × 0.65 × 3.0 mm. Following preparation of data, images will be moved to Philips Workstation software suite for additional processing.

(Group 2):

In this study, sixteen healthy controls, matched for age, were examined for comparative purposes, consisting of ten females and six

males. These individuals had no contraindications for MRI examinations and exhibited no history or signs of any neurological disorder. They underwent the same MRI examination protocol, utilizing identical parameters as those applied to our patients.

Statistical Analysis:

The gathered data underwent coding, processing, and analysis utilizing the SPSS software (Version 25) for the windows operating system. Descriptive statistics were computed, encompassing means, standard deviations, medians, ranges, and percentages. mean values of continuous variables were analyzed using independent t-tests that were normally distributed, whereas Mann-Whitney U tests were employed to evaluate the median variations in data that did not meet normal distribution criteria, along with categorical variables were examined using chi-square testing. A p-value of below 0.05 was deemed statistically significant. P value greater than 0.05 indicates a lack of significance, p greater than 0.001 is regarded as highly significant. Figures were done using Microsoft Excel 365.

Ethical Approval:

The study was approved by the Ethical Committee of Scientific Research at Faculty of medicine, Minia University (Approval no. and date: 1264/09/2024). Informed consent was secured from all patients as well as healthy controls.

Results

A total of twelve patients diagnosed with multiple sclerosis (MS) participated in this study, all patients included were female mean age ± SD (34.08 ± 6.41). Control group included 6 males (37.5%) and 10 females (62.5%), mean age ± SD (32.37 ± 6.35).

Regarding DTI, among MS patients, it was found that mean ± SD of fractional anisotropy (FA) at regions of normal appearing white matter (NAWM) 0.4 ± 0.03, and mean ± SD of FA at lesions 0.23 ± 0.04, having a difference that is statistically highly significant (P value ≤0.001). Table (1)

Moreover, it was found that mean ± SD of FA at NAWM of MS patients 0.4 ± 0.03, and mean ± SD of FA at white matter of controls 0.56 ± 0.06, with statistically significant difference (P value <0.01). Table (2)

Regarding site of lesions in MS patients, it was found that lesions were periventricular in 100% of patients, subcortical in 66.6%, cortical and juxtacortical in 58.3%, and at infratentorial region in 25%. Table (3)

Central vein sign, diagnosed by SWI, was seen periventricular in 10 patients (83.3%), subcortical in 58.3%, cortical and juxtacortical in 33.3%, and at infratentorial region in 16.6%. Table (4)

More importantly, central vein sign diagnosed by SWI, was seen in 172 MS lesions out of a total no. of 363 in all studied patients, with a percent of (47.3%). All studied patients had more than 6 central vein sign lesions.

Table (1): FA at normal appearing white matter (NAWM) & MS lesions among patients.

MS patients N=12	
FA at NAWM Mean ± SD	0.4 ±0.03
FA at lesions Mean ± SD	0.23 ±0.04
P value	**≤0.001****

Table (2): FA at NAWM of MS patients & FA at white matter of controls

	FA at NAWM of MS patients N=12	FA at white matter of controls N=16	P value
Mean ± SD	0.4 ± 0.03	0.56 ± 0.06	**<0.01***

Table (3): Site of the lesions among patients with MS

Site of the lesions	MS patients N=12
Periventricular	12 (100%)
Subcortical	8 (66.6%)
Cortical and juxtacortical	7 (58.3%)
Infratentorial	3 (25%)

Table (4): Central vein sign observed in patients with MS

MS patients N=12	
Central vein sign	
Periventricular	10 (83.3%)
Subcortical	7 (58.3%)
Cortical and juxtacortical	4 (33.3%)
Infratentorial	2 (16.6)

Discussion

The existing standard MRI sequences are insufficient for providing dependable information regarding the condition of brain tissues, which restricts their capacity to predict clinical outcomes accurately [(8)]. Diffusion tensor imaging and susceptibility weighted imaging are advanced MRI methodologies which are effectively address this limitation. Diffusion Tensor Imaging (DTI) assesses the water particles movement within brain matter, offering comprehensive insights into the microstructure and integrity of white matter [(9)]. SWI enhances DTI and other MRI techniques by offering supplementary contrast associated with tissue composition and vascular alterations, thereby improving the comprehensive neuroimaging evaluation [(10)].

Regarding DTI, among MS patients, we found that FA at NAWM was 0.4 ± 0.03, and at lesions 0.23 ± 0.04, with statistically highly significant difference. Moreover, it was found that FA at NAWM of MS patients was 0.4 ± 0.03, and at white matter of normal healthy controls 0.56 ± 0.06, with statistically significant difference. Our findings were in alignment with Chen et al., (2017) who studied FA values at MS lesions across various stages in 10 patients alongside 10 healthy controls. Their findings indicated that the FA values of MS lesions were reduced in comparison to those of NAWM and the normal controls. Furthermore, the FA values of NAWM were found to be lower than those of normal white matter in healthy controls [(11)].

Regarding the location of MS lesions in our sample, it was found that lesions were periventricular in 100% of patients, subcortical in 66.6% of patients, cortical and juxtacortical in 58.3%, and at infratentorial region in 25%. These results were in alignment with the research carried out by Pongratz et al., (2023) who found that periventricular and subcortical regions are the most frequently affected [(12)].

Central vein sign diagnosed by SWI in our study was seen periventricular in 10 patients (83.3%), subcortical in 58.3%, cortical and juxtacortical in 33.3%, and at infratentorial region in 16.6%. Our results were to a considerable extent agreed with the research carried out by Sparacia et al., (2018) who found that central vein sign identified in 128 lesions associated with multiple sclerosis (40.9%), with the majority of these lesions being (55.5%) had a periventricular distribution [13].

In our study, central vein sign (CVS), diagnosed by SWI, was seen in 172 MS lesions out of a total no. of 363 in all studied patients, with a percent of (47.3%). That was in agreement with results of the Egyptian cohort studied by Abdel Ghany et al., (2022) who considered 45% as a cut off value; 45% CVS-positive lesion threshold can be a **highly specific and fairly sensitive** biomarker for MS diagnosis in both typical and atypical clinical scenarios [14].

All studied patients had more than 6 central vein sign lesions, and the total percent of (47.3%) CVS-positive lesion are in agreement with the ECTRIMS (2024) revisions of the McDonald criteria that used CVS for improving diagnostic specificity for multiple sclerosis [15].

Conclusion

DTI and SWI are non-conventional brain MRI techniques that significantly help in studying and diagnosing patients with MS.

References

1. McGinley MP, Goldschmidt CH, Rae-Grant AD. Diagnosis and Treatment of Multiple Sclerosis: A Review. Jama. 2021; 325 (8): 765-79.
2. Rahmanzadeh R, Lu P, Barakovic M, Weigel M, Maggi P, Nguyen TD, et al. Myelin and Axon Pathology in Multiple Sclerosis Assessed by Myelin Water and Multi-Shell Diffusion Imaging. Brain. 2021; 144 (6): 1684-96.
3. Kamagata K, Andica C, Kato A, Saito Y, Uchida W, Hatano T, et al., Diffusion Magnetic Resonance Imaging-Based Biomarkers for Neurodegenerative Diseases. International Journal of Molecular Sciences. 2021; 22 (10): 5216.
4. Conti L, Preziosa P, Meani A, Pagani E, Valsasina P, Marchesi O, et al., Unraveling the Substrates of Cognitive Impairment in Multiple Sclerosis: A Multiparametric Structural and Functional Magnetic Resonance Imaging Study. European Journal of Neurology. 2021; 28 (11): 3749-59.
5. Abdelgawad EA, Amin MF, Abdellatif A, Mourad MA, Abusamra MF. Value of Susceptibility Weighted Imaging (SWI) in Assessment of Intra-Arterial Thrombus in Patients with Acute Ischemic Stroke. Egyptian Journal of Radiology and Nuclear Medicine. 2021; 52: 1-8.
6. Chaaban L, Safwan N, Moussa H, El-Sammak S, Khoury SJ, Hannoun S. Central Vein Sign: A Putative Diagnostic Marker for Multiple Sclerosis. Acta Neurologica Scandinavica. 2022; 145 (3): 279-87.
7. Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, et al., Diagnosis of Multiple Sclerosis: 2017 Revisions of the Mcdonald Criteria. The Lancet Neurology. 2018; 17 (2): 162-173.
8. Vargas MI, Delattre BMA, Boto J, Gariani J, Dhouib A, Fitsiori A, et al., Advanced Magnetic Resonance Imaging (MRI) Techniques of the Spine and Spinal Cord in Children and Adults. Insights into imaging. 2018; 9: 549-57.
9. Ranzenberger LR, Das JM, Snyder T. Diffusion Tensor Imaging. In Statpearls [Internet]: StatPearls Publishing, 2023.
10. Sotoudeh H, Sarrami AH, Wang J, Saadatpour Z, Razaei A, Gaddamanugu S, et al. Susceptibility-Weighted Imaging in Neurodegenerative Disorders: A Review. Journal of Neuroimaging. 2021; 31 (3): 459-70.
11. Chen J, Zhou C, Zhu L, Yan X, Wang Y, Chen X, et al., Magnetic Resonance Diffusion Tensor Imaging for Occult Lesion Detection in Multiple Sclerosis. Experimental and therapeutic medicine. 2017; 13 (1): 91-96.
12. Pongratz V, Bussas M, Schmidt P, Grahl S, Gasperi C, El Husseini M, et al., Lesion Location across Diagnostic Regions in Multiple Sclerosis. NeuroImage: Clinical. 2023; 37: 103311.
13. Sparacia G, Agnello F, Gambino A, Sciortino M, Midiri M. Multiple Sclerosis: High Prevalence of the 'Central Vein' sign in White Matter Lesions on Susceptibility-

Weighted Images. The neuroradiology journal. 2018; 31 (4): 356-61.

14. Abdel Ghany H, Karam-Allah A, Edward R, Abdel Naseer M, Hegazy MI. Sensitivity and specificity of central vein sign as a diagnostic biomarker in Egyptian patients with multiple sclerosis. Neuropsychiatr Dis Treat. 2022; 18:1985-1992.

15. Thompson AJ, Banwell BL, Barkhof F, Carroll WM, Coetzee T, Comi G, et al., 2024 Revisions to the McDonald Diagnostic Criteria for Multiple Sclerosis. European Committee for Treatment and Research in Multiple Sclerosis (ECTRIMS); 2024. Available from: https://ectrims.eu/mcdonald-diagnostic-criteria.