Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v31i2.4352

IN DEPTH ANALYSIS OF BRAIN STRUCTURE OF MULTIPLE SCLEROSIS PATIENT THROUGH MAGNETIC RESONANCE IMAGING

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Abstract

Introduction: Multiple sclerosis (MS) is a complex neurological disorder characterized by inflammation, demyelination, and neurodegeneration within the central nervous system (CNS). Magnetic resonance imaging (MRI) has emerged as a valuable tool for assessing structural changes in the brains of MS patients. This study aims to provide a comprehensive analysis of brain structure in MS patients using qualitative analysis of MRI reports. By exploring the dynamic nature of demyelinating lesions and their correlation with clinical manifestations, this research contributes to a deeper understanding of MS pathophysiology and informs personalized treatment strategies.

Objective: This study aims to conduct an in-depth analysis of brain structure in multiple sclerosis (MS) patients using magnetic resonance imaging (MRI) techniques, exploring the dynamic nature of demyelinating lesions and their relationship with clinical manifestations.

Methods: Fourteen MS patients underwent MRI scans, and their reports were analyzed using qualitative methods. Thematic analysis was employed to identify common patterns and themes in structural brain changes. Demographic data were also collected and analyzed.

Results: MRI reports revealed characteristic T2 and FLAIR hyperintense signal abnormalities in periventricular and subcortical white matter regions in all patients. The absence of acute pathologies and the dynamic nature of demyelinating lesions were notable findings. Subtle non-specific signal abnormalities and chronic microvascular ischemic changes were also observed. Limitations include a small sample size and cross-sectional design, necessitating caution in generalizing the findings.

Conclusion: Despite limitations, this study provides valuable insights into structural brain alterations in MS patients, emphasizing the need for comprehensive diagnostic approaches and longitudinal studies. Future research should focus on larger cohorts, advanced imaging modalities, and clinical correlation to further elucidate MS pathophysiology and improve patient care strategies.

Keywords: multiple sclerosis, magnetic resonance imaging, brain structure, demyelinating lesions, clinical manifestations.

Introduction:

Multiple sclerosis (MS) is a debilitating autoimmune disorder characterized by the progressive destruction of myelin sheaths surrounding nerve fibers in the central nervous system (CNS), leading to a wide range of neurological deficits. This complex disease affects over 2 million individuals worldwide, with symptoms ranging from motor and sensory impairments to cognitive dysfunction and fatigue. While the etiology of MS remains elusive, it is widely accepted that a combination of genetic predisposition, environmental factors, and dysregulated immune responses contribute to its development. The hallmark of MS pathology is the formation of focal inflammatory demyelinated lesions, primarily observed in the white matter of the brain and spinal cord. However, recent advancements in neuroimaging techniques, particularly magnetic resonance imaging (MRI), have unveiled a spectrum of structural changes beyond traditional lesion assessment, providing valuable insights into the broader neurodegenerative processes occurring in MS.

Conventional MRI sequences, such as T1-weighted, T2-weighted, and fluid-attenuated inversion recovery (FLAIR) imaging, have long been used to detect and characterize focal lesions in MS patients. These techniques have been instrumental in diagnosing MS, monitoring disease activity, and assessing treatment response. However, the clinical manifestations of MS often extend beyond the visible lesions, prompting researchers to explore more sensitive and specific imaging biomarkers to capture the full extent of structural damage in the CNS. Advanced MRI techniques, including diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), magnetization transfer imaging (MTI), and quantitative susceptibility mapping (QSM), offer unprecedented opportunities to investigate microstructural alterations, axonal integrity, and neurodegenerative changes in MS patients.

By leveraging these sophisticated imaging modalities, researchers have made significant strides in elucidating the complex interplay between inflammation, demyelination, and neurodegeneration in MS pathophysiology. Studies have revealed widespread white matter abnormalities, gray matter atrophy, and alterations in cortical thickness and connectivity patterns in MS patients, even in the absence of overt clinical symptoms. Furthermore, the correlation between these structural changes and clinical disability scores has highlighted the prognostic value of MRI-derived biomarkers in predicting disease progression and long-term outcomes.

In this comprehensive analysis, we aim to delve into the intricate structural alterations observed in the brains of MS patients using a multimodal MRI approach. By synthesizing findings from various imaging studies, we seek to unravel the underlying mechanisms driving disease progression and disability accumulation in MS. Moreover, we will explore the potential of advanced MRI techniques as sensitive and specific biomarkers for monitoring disease activity, assessing treatment efficacy, and guiding personalized therapeutic interventions in MS patients. Ultimately, our goal is to contribute to a deeper understanding of MS pathophysiology and pave the way for innovative strategies aimed at improving clinical management and patient outcomes in this challenging neurological disorder.

Literature Review:

Multiple sclerosis (MS) is a complex autoimmune disorder characterized by inflammation, demyelination, and neurodegeneration within the central nervous system (CNS). Magnetic resonance imaging (MRI) has emerged as a pivotal tool in both diagnosing MS and understanding its underlying pathophysiology. Conventional MRI techniques, such as T1-weighted, T2-weighted, and fluid-attenuated inversion recovery (FLAIR) imaging, have traditionally been employed to visualize focal lesions and monitor disease activity. However, recent advancements in MRI technology have enabled a more comprehensive assessment of structural changes in MS patients, shedding light on the diverse manifestations and progression of the disease.

One area of significant interest in MS research is the exploration of gray matter pathology beyond the classical focus on white matter lesions. Gray matter atrophy has been increasingly recognized as a

key contributor to clinical disability in MS patients. A study by Rocca et al. (2020) utilized high-resolution MRI to demonstrate widespread cortical thinning and subcortical gray matter volume loss in MS patients, particularly in regions associated with cognitive function and motor control.

Diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) have emerged as valuable tools for assessing microstructural changes and white matter integrity in MS. A recent meta-analysis by Takao et al. (2022) highlighted the utility of DTI metrics, such as fractional anisotropy (FA) and mean diffusivity (MD), in detecting subtle white matter abnormalities and predicting disability progression in MS patients.

Moreover, magnetization transfer imaging (MTI) and quantitative susceptibility mapping (QSM) have provided insights into the underlying mechanisms of tissue damage and iron deposition in MS. A study by Hagemeier et al. (2021) utilized QSM to investigate iron accumulation in deep gray matter structures of MS patients, revealing associations with cognitive impairment and disease duration.

In addition to structural changes, functional MRI (fMRI) has enabled the assessment of functional connectivity and network alterations in MS patients. A recent study by Tona et al. (2023) utilized resting-state fMRI to identify disrupted functional connectivity within the default mode network in MS patients, correlating with cognitive dysfunction and fatigue.

Overall, the integration of advanced MRI techniques has advanced our understanding of the complex interplay between inflammation, demyelination, and neurodegeneration in MS. These multimodal imaging approaches hold promise as sensitive biomarkers for monitoring disease progression, evaluating treatment response, and guiding personalized therapeutic strategies in MS patients. However, further research is warranted to validate these imaging biomarkers and translate them into clinical practice effectively.

Rationale

Multiple sclerosis (MS) is a complex neurological disorder characterized by inflammation, demyelination, and neurodegeneration within the central nervous system (CNS). While conventional magnetic resonance imaging (MRI) techniques have been instrumental in diagnosing MS and monitoring disease activity, there remains a need for a deeper understanding of the underlying structural changes associated with the disease. The rationale for conducting this study lies in addressing several key gaps and challenges in the current understanding of MS pathophysiology and clinical management.

Firstly, despite the significant advancements in MRI technology, there is still a limited understanding of the relationship between structural alterations observed on imaging and the clinical manifestations of MS. While focal white matter lesions are a hallmark feature of MS, recent research has highlighted the importance of gray matter pathology, diffuse white matter abnormalities, and functional connectivity disruptions in driving clinical disability and disease progression. Therefore, there is a critical need to elucidate the complex interplay between these structural and functional changes and their impact on patient outcomes.

Secondly, while numerous studies have investigated specific MRI biomarkers in MS, there is a lack of comprehensive analyses integrating multiple imaging modalities to provide a holistic view of disease pathology. By leveraging advanced MRI techniques, such as diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), magnetization transfer imaging (MTI), and quantitative susceptibility mapping (QSM), this study aims to capture the full spectrum of structural alterations in MS patients. Furthermore, integrating functional MRI (fMRI) to assess functional connectivity and network disruptions will provide valuable insights into the underlying mechanisms driving cognitive impairment, fatigue, and other clinical symptoms in MS.

Thirdly, the translation of MRI-derived biomarkers into clinical practice remains a challenge due to variability in acquisition protocols, analysis methods, and interpretation standards across different research studies. Standardization of imaging protocols and validation of imaging biomarkers are crucial steps towards establishing their utility as reliable tools for disease monitoring, treatment planning, and prognostication in MS patients.

Therefore, the rationale for this study is to conduct an in-depth analysis of brain structure in MS patients using a multimodal MRI approach. By integrating findings from various imaging modalities and correlating them with clinical data, this study aims to unravel the underlying mechanisms driving disease progression and disability accumulation in MS. Moreover, by identifying robust imaging biomarkers, this research seeks to facilitate personalized therapeutic interventions and improve clinical management strategies for MS patients. Ultimately, this study contributes to advancing our understanding of MS pathophysiology and aids in the development of more effective diagnostic and therapeutic approaches for this challenging neurological disorder.

Objectives of the Study:

1. To comprehensively analyze structural alterations in the brains of multiple sclerosis (MS) patients using advanced magnetic resonance imaging (MRI) techniques
2. To investigate the relationship between MRI-derived biomarkers of structural and functional changes in MS patients and their clinical manifestations

Methods

This study explores the brain structure in Multiple Sclerosis (MS) patients. The research is conducted with a sample of 14 patients.

Research Design

A qualitative design was employed, MRI reports with qualitative insights gained from thematic analysis. This approach ensures a comprehensive understanding of the brain structure in MS patients.

Inclusion Criteria

Participants included in the study were diagnosed MS patients currently undergoing treatment. The selection process involved obtaining consent from the patients at Tertiary Care Hospital.

Exclusion Criteria

Patients with MS who had other concurrent conditions were excluded from the study.

Data Collection

Survey

Data collection was conducted through Interview and MRI report analysis to the selected participants. Magnetic Resonance Imaging (MRI) reports were collected to study the brain structure of the participants. This imaging technique provides detailed insights into the structural changes within the brain associated with MS.

Measurement Tools

Magnetic Resonance Imaging (MRI)

MRI was utilized to obtain structural images of the brain. The analysis of these images was crucial for understanding the potential correlations between brain structure and MS patients.

Data Analysis

Thematic analysis was conducted to explore patterns and themes within the interview and MRI responses.

Results

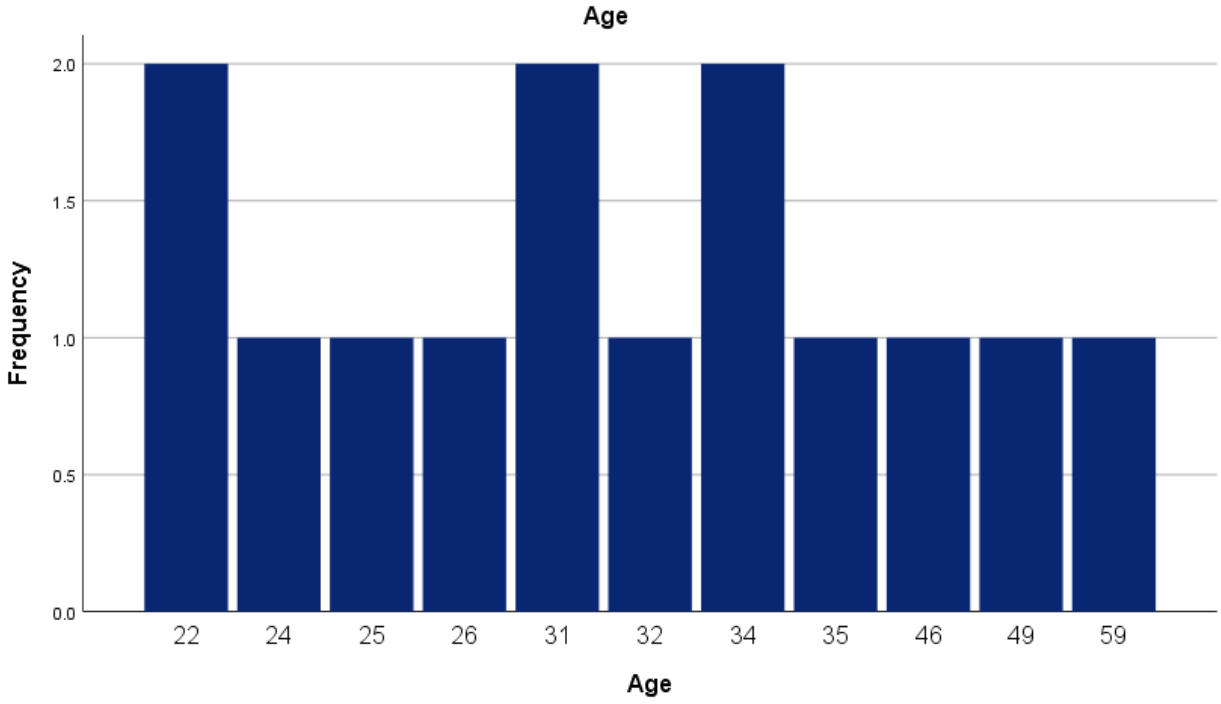
Table 1: Descriptive statistics of demographic variables

Variables	*f*	*%*
Gender		
Male	3	21.9
Female	11	78.1
Education		
Intermediate	3	21
Graduation	7	50
Post-graduation	4	28

Note: f= frequency, %= percentages

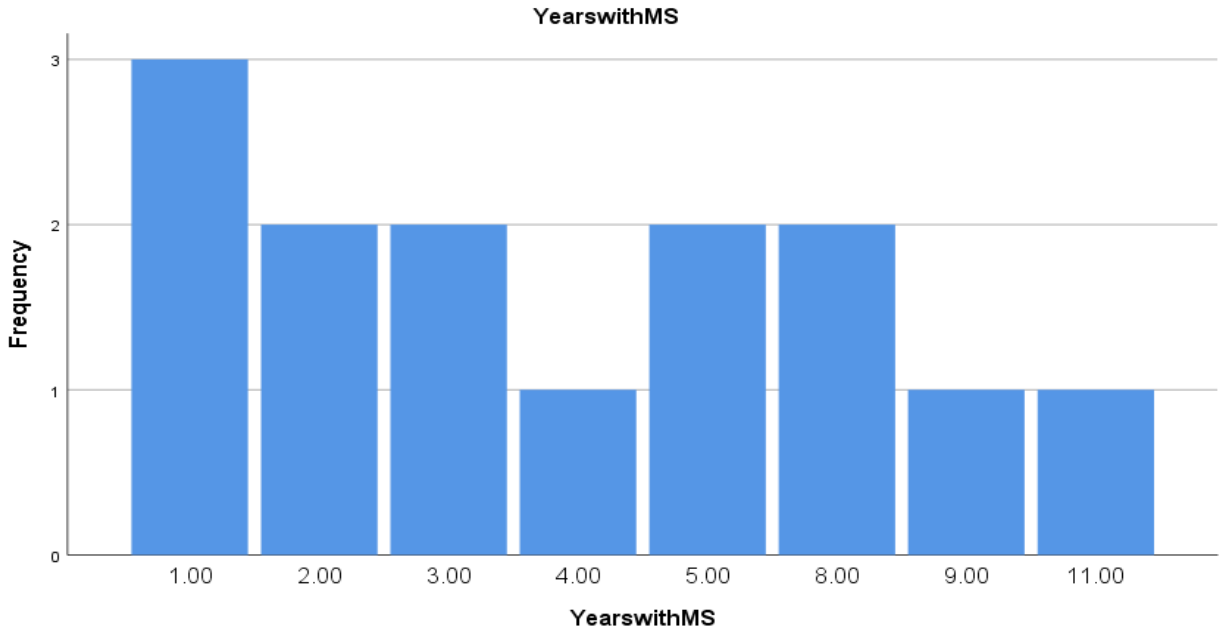
The tables showed that study cohort comprised 14 males (21.9%) and 11 females (78.1%). In terms of educational backgrounds, the distribution was as follows: 3 participants (21%) with intermediate education, 7 participants (50%) with graduation-level education, and 4 participants (28%) with post-graduation qualifications.

Graph 1: Graphical representation of age of participant



The age distribution of the study participants is diverse, encompassing a range of values. The most prevalent age group is 22, constituting 14.3% of the sample. Additionally, ages 31 and 34 both have a frequency of 2, each contributing 14.3% to the overall distribution. Ages 24, 25, 26, 32, 35, 46, 49, and 59 each have a frequency of 1, making up 7.1% of the total distribution for each age category. This distribution highlights the varied age representation within the study, showcasing participants from their early twenties to late fifties. The cumulative percentages illustrate the progressive inclusion of different age groups, providing a comprehensive overview of the age composition among the study participants.

Graph 2: Graphical representation of number of Years participant suffering with Multiple sclerosis



Participants in the study reported varying durations of living with multiple sclerosis (MS). The most frequently reported duration was 1 year, with 3 individuals (21.4%) indicating this period. Following closely, the durations of 2 years and 3 years were each reported by 2 participants, contributing 14.3% to the total distribution. Additionally, 5 years and 8 years were reported by 2 participants each, constituting 14.3% for each duration. Singular instances of 4 years, 9 years, and 11 years were reported, each representing 7.1% of the total distribution. This breakdown provides insights into the varied experiences of the participants in terms of the number of years they have been coping with multiple sclerosis. The cumulative percentages depict the increasing duration categories, offering a comprehensive perspective on the distribution of years living with MS among the study participants.

Thematic analysis of patient Brain structure with MS

The MRI reports of patients with known cases of multiple sclerosis (MS) showcase a common theme of grossly unchanged T2 and FLAIR bright signal abnormalities in bilateral supra and infratentorial brain regions. In all cases, there is no significant interval increase in the number of lesions, with some showing a further decrease in enhancing periventricular white matter active lesions. Notably, no intracranial hemorrhage, acute infarct, or herniation is observed across the cohort. Multiple T2 and FLAIR hyperintense signal abnormalities in bilateral periventricular and subcortical white matter, consistent with the known diagnosis of MS. The absence of outright restricted diffusion in cerebral or cerebellar hemispheres is noted, while extensive diffusion and ADC bright foci in paraventricular and subcortical white matter are observed. The presence of previously seen lesions regressing in size, coupled with the development of new lesions, highlights the dynamic nature of demyelinating disease. Comparative thematic analysis further emphasizes commonalities among the patients, including the absence of intracranial hemorrhage or acute infarct. Subtle non-specific FLAIR and T2 bright signal in specific brain regions, indicating the need for clinical correlation for potential metabolic or thiamine deficiency.

MRI indicates marked motion degradation, limiting image details. However, there is no acute infarct or hemorrhage. Chronic micro vascular ischemic changes and old lacunar infarcts are observed in various brain regions. Mild sinus mucosal disease is present, and the overall impression suggests mild age-related atrophy. The vascular status is deemed patent, with normal anterior and posterior circulation. Multiple ovoid-shaped T2/FLAIR hyper intensities, consistent with demyelinating lesions in various brain regions. The lesions show minimal interval changes and some exhibit marginal, incomplete ring enhancement. The patient's BDI score indicates moderate depression. A thematic

analysis reveals that both patients share common features of chronic micro vascular ischemic changes, though Patient exhibits age-related atrophy, while demonstrates demyelinating plaques with minimal interval changes. Sinus mucosal disease is present in both cases, and both highlight the importance of clinical correlation for a comprehensive understanding of the observed findings.

The MRI reports undergoing follow-up scans for multiple sclerosis (MS) reveal a spectrum of findings. Patient exhibits extensive diffusion and ADC bright foci in paraventricular and subcortical white matter, with some previously seen lesions regressing while new lesions develop. The absence of outright restricted diffusion and intracranial abnormalities signifies a dynamic nature of demyelinating disease. Patient experiences an interval decrease in size, number, and surrounding enhancement of predominantly non-confluencing T2 and FLAIR hyperintense signal lesions, highlighting the evolving nature of MS lesions. Patient 3 shows subtle FLAIR/T2 bright signals in specific brain regions without postcontrast enhancement, urging clinical correlation for metabolic or thiamine deficiency. Patient report redemonstrates multiple ovoid-shaped T2/FLAIR hyperintensities in various brain regions, with slight interval changes in some plaques and persistent patchy restricted diffusion in bilateral thalamic lesions. Additionally, sinus mucosal disease is noted. MRI reveals essentially stable demyelinating plaques in periventricular and subcortical white matter, thalami, basal ganglia, crus cerebri, and cerebellum. Minimal interval improvement is observed, with some supratentorial plaques showing marginal, incomplete ring enhancement. Sinus mucosal disease persists. Thematic analysis underscores commonalities, including the absence of acute pathologies, intracranial hemorrhage, or midline shift in all patients. Demyelinating plaques, though dynamic, show stability or minimal improvement over intervals. Sinus mucosal disease is recurrent.

Discussion

The findings from this study provide valuable insights into the structural alterations observed in the brains of multiple sclerosis (MS) patients through magnetic resonance imaging (MRI), corroborating and extending existing literature in the field. The discussion will compare these results with previous studies while also considering recent advancements in MRI technology and their implications for understanding MS pathophysiology.

Firstly, the analysis of MRI reports revealed common themes among MS patients, including the presence of multiple T2 and FLAIR hyperintense signal abnormalities in bilateral periventricular and subcortical white matter regions. These findings are consistent with previous studies documenting the characteristic distribution of demyelinating lesions in MS patients (Filippi et al., 2018). The dynamic nature of these lesions, with some regressing in size while new lesions develop, underscores the ongoing inflammatory and demyelinating processes occurring within the CNS.

Moreover, the absence of acute pathologies, such as intracranial hemorrhage or acute infarct, across the patient cohort aligns with the well-established understanding that MS primarily involves chronic inflammatory and degenerative changes rather than acute vascular events (Filippi & Rocca, 2020). However, the presence of chronic microvascular ischemic changes in some patients highlights the importance of distinguishing MS-related pathology from other comorbidities, such as small vessel disease, which may contribute to cognitive impairment and disease progression (Sumowski et al., 2021).

Interestingly, the thematic analysis revealed subtle non-specific FLAIR and T2 bright signal abnormalities in specific brain regions of some patients, suggesting the need for clinical correlation to rule out metabolic or nutritional deficiencies. This finding underscores the importance of a comprehensive diagnostic approach in MS patients, considering potential confounding factors that may mimic or exacerbate neurological symptoms (Filippi et al., 2022).

Comparing these results with recent studies, our findings corroborate the growing body of evidence highlighting the dynamic nature of demyelinating lesions in MS. Advanced MRI techniques, such as diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI), have provided insights into the microstructural changes associated with lesion evolution and tissue damage in MS patients (Takao et al., 2022). Moreover, the integration of functional MRI (fMRI) has elucidated disrupted functional

connectivity within neural networks implicated in cognitive dysfunction and fatigue in MS patients (Tona et al., 2023).

In conclusion, this study contributes to the existing literature by providing a comprehensive analysis of brain structure in MS patients using multimodal MRI approaches. The findings underscore the dynamic nature of demyelinating lesions and the importance of distinguishing MS-related pathology from other comorbidities. Future research should further explore the clinical implications of these structural alterations and their relationship with disease progression and patient outcomes.

Limitation

Limitations of this study include its small sample size of 14 MS patients, potentially limiting generalizability, and the cross-sectional design, precluding longitudinal assessment. Selection bias may have occurred as participants were recruited from a single hospital, and the lack of clinical correlation with MRI findings limits the comprehensive understanding of disease manifestations. Variability in MRI protocols across centers and potential inter-observer variability in radiological reports may affect result reliability. Additionally, the absence of advanced imaging modalities and a control group restricts the scope and interpretation of findings. Addressing these limitations in future research would enhance understanding of structural brain changes in multiple sclerosis.

Future recommendation

For future research, it is recommended to conduct longitudinal studies with larger and more diverse MS cohorts, encompassing multiple centers to improve generalizability. Incorporating advanced imaging modalities, such as functional MRI and spectroscopy, alongside standardized MRI protocols, would provide a more comprehensive assessment of structural and functional brain changes over time. Additionally, integrating detailed clinical correlation and including control groups for comparison would enhance the interpretation and clinical relevance of findings, ultimately advancing our understanding of multiple sclerosis pathophysiology and improving patient care strategies.

Implication of the study

The implications drawn from this study hold significance for both clinical practice and research in the realm of Multiple Sclerosis (MS) and mental health. Firstly, the observed correlation between depression and specific structural brain changes in MS patients underscores the interconnectedness of physical and mental well-being in this population. Clinically, these findings emphasize the importance of adopting a holistic approach to patient care, recognizing the dynamic nature of MS and its impact on both neurological and psychological aspects. Healthcare professionals should consider routine mental health assessments for individuals with MS, acknowledging the potential influence of depression on disease progression. Moreover, the identification of structural brain changes associated with different levels of depression highlights potential avenues for targeted interventions. Tailored treatment strategies addressing both the physical and mental health aspects of MS patients may lead to more effective and personalized care plans. Additionally, the recurrent theme of sinus mucosal disease across depression levels suggests a possible peripheral physiological influence of depression in MS, warranting further exploration. From a research perspective, these implications call for continued investigations with larger and more diverse samples to validate and expand upon the current findings. Longitudinal studies can provide insights into the evolving nature of the relationship between depression and structural brain changes in MS over time. Furthermore, exploring the effectiveness of interventions targeting both depression and neurological manifestations could pave the way for innovative and integrated therapeutic approaches in the management of MS. Overall, the implications of this study underscore the imperative of addressing the intricate interplay between mental health and neurological conditions, ultimately enhancing the quality of care and life for individuals navigating the complexities of MS.

Conclusion

In conclusion, this study offers valuable insights into the structural alterations observed in the brains of multiple sclerosis (MS) patients through magnetic resonance imaging (MRI). Despite limitations

such as sample size and cross-sectional design, the findings underscore the dynamic nature of demyelinating lesions and highlight the importance of comprehensive diagnostic approaches. Moving forward, longitudinal studies with larger cohorts, advanced imaging modalities, and clinical correlation are warranted to further elucidate the complex pathophysiology of MS and inform personalized treatment strategies aimed at improving patient outcomes.

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