International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Mapping CNS Lesions: MRI Study of Incidence, Types, and Prognostic Patterns in a Retrospective Study

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Abstract: ***Magnetic resonance imaging (MRI) is a cornerstone in diagnosing central nervous system (CNS) lesions, encompassing diverse pathological types such as neoplastic, vascular, inflammatory, infectious, and degenerative. This retrospective cohort study analyzed 986 patients, identifying incidence patterns and evaluating prognostic indicators through MRI. Results highlighted a high prevalence of neoplastic (43.8%) and vascular (27.5%) lesions. Advanced MRI modalities were instrumental in lesion classification and survival prediction, emphasizing MRI's critical role in CNS pathology management. The study underscores the need for further research to refine imaging - based clinical strategies.***

Keywords: CNS lesions, MRI, lesion classification, prognostic imaging, retrospective study.

1. Introduction

Central nervous system (CNS) lesions are a diverse group of pathological entities encompassing neoplastic, inflammatory, vascular, infectious, and degenerative processes. These lesions present significant diagnostic and prognostic challenges due to their varied presentations and overlapping radiological features. Magnetic resonance imaging (MRI) has emerged as a cornerstone in the evaluation of CNS lesions, offering unparalleled soft - tissue contrast, spatial resolution, and functional imaging capabilities. Understanding the patterns of incidence, lesion types, and their prognostic implications through imaging is critical for optimizing patient management and advancing clinical outcomes (1). Although numerous studies have focused on specific types of CNS lesions, comprehensive assessments of their incidence, classification, and prognosis within a single cohort are limited. A retrospective analysis integrating these aspects provides valuable insights into the natural history of CNS pathologies and their radiological characteristics. This study aims to map the spectrum of CNS lesions in a single - center retrospective cohort using MRI, with a focus on incidence, lesion characterization, and prognostic markers. By bridging gaps in the existing literature, this work seeks to inform clinical decision - making and contribute to the growing body of evidence on CNS pathology.

CNS lesions encompass a wide range of conditions affecting the brain and spinal cord, with significant implications for morbidity, mortality, and quality of life. The incidence of CNS lesions varies globally, influenced by factors such as age, geographic location, and healthcare access (1). Tumorous lesions, including glioblastomas, meningiomas, and metastatic lesions, represent the most frequently studied category, yet non - neoplastic conditions like multiple sclerosis, cerebral infarcts, and abscesses also contribute substantially to the disease burden (2, 3). Accurate characterization of these lesions is essential for establishing a diagnosis and predicting prognosis.

MRI has revolutionized the approach to CNS imaging, offering advanced modalities such as diffusion - weighted imaging (DWI), perfusion imaging, and spectroscopy. These techniques facilitate the differentiation of lesion types, assessment of functional and metabolic parameters, and identification of biomarkers associated with disease progression and treatment response (4). Recent advancements in artificial intelligence (AI) have further enhanced MRI - based lesion analysis by enabling automated segmentation and risk stratification (5).

Despite these technological strides, the literature reveals significant heterogeneity in the reported prevalence and prognostic patterns of CNS lesions. Retrospective cohort studies that systematically examine MRI findings across diverse lesion types and link them with clinical outcomes are relatively sparse. This highlights the need for targeted research exploring the interplay between lesion type, imaging characteristics, and prognosis within a defined population.

The rationale for this study lies in addressing critical knowledge gaps in the epidemiology and imaging of CNS lesions. While prior research has predominantly focused on specific pathologies or imaging techniques, there is a lack of integrative studies examining lesion incidence, classification, and prognosis. The retrospective design allows for the evaluation of real - world data, offering insights into clinical patterns and outcomes that may not be captured in prospective trials.

By leveraging MRI as the primary diagnostic tool, this study provides an opportunity to comprehensively analyze CNS lesion characteristics and their prognostic implications in a diverse cohort. Such research is essential for advancing our

understanding of disease mechanisms, refining diagnostic algorithms, and developing personalized treatment strategies. Moreover, the findings may serve as a reference point for future studies and contribute to the formulation of evidence - based guidelines in neuroimaging and CNS disease management.

Objectives

- To identify and categorize the various types of CNS lesions detected in the local population using MRI.
- To estimate the incidence rates of these lesions within the study group.
- To evaluate MRI findings and their patterns, examining their association with clinical outcomes to offer prognostic insights based on specific imaging features.

2. Materials and Methods

Study Design: This was a retrospective, single - center cohort study designed to evaluate the incidence, categorization, and prognostic patterns of central nervous system (CNS) lesions identified using magnetic resonance imaging (MRI). The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and approved by the institutional review board (IRB). Informed consent was waived due to the retrospective nature of the study and the de - identification of patient data.

Study Setting and Population: The study was conducted at Sri lakshmi Narayana Institute of medical Sciences a tertiary care hospital. The study population included patients who underwent an MRI of the brain and/or spinal cord for clinical indications between 30th December 2024 to 1st January 2020 (Retrospectively). The inclusion and exclusion criteria were as follows:

Inclusion Criteria:

- Patients of all age groups who underwent MRI for neurological symptoms (e. g., headache, seizures, motor or sensory deficits).
- Availability of complete imaging datasets with diagnostic - quality MRI sequences.
- Documented clinical outcomes in medical records, including treatment response and follow - up data.

Exclusion Criteria:

- Patients with incomplete imaging data or non - diagnostic - quality MRIs.
- History of prior CNS surgery or lesions treated before the study period.
- Inadequate clinical documentation regarding outcomes.

MRI Protocol: MRI scans were performed using a 1.5 Tesla (T) [Magnetom Essenza] system. Standardized imaging protocols were applied to ensure consistency and diagnostic quality. The following sequences were included in all studies:

- **T1 - weighted imaging (T1WI):** Pre - and post - contrast for structural evaluation.
- **T2 - weighted imaging (T2WI):** For detecting edema, cystic changes, and fluid accumulation.
- **Fluid - attenuated inversion recovery (FLAIR):** To highlight lesions near cerebrospinal fluid (CSF) spaces.
- **Diffusion - weighted imaging (DWI):** For characterizing ischemic and cytotoxic changes.
- **Susceptibility - weighted imaging (SWI):** To identify hemorrhagic or calcified lesions.
- **Magnetic resonance spectroscopy (MRS):** For metabolic and biochemical profiling of lesions in selected cases.

All images were independently reviewed by two experienced radiologists blinded to clinical outcomes, and discrepancies were resolved by consensus.

Data Collection

Clinical, demographic, and imaging data were extracted from the hospital's electronic medical records and imaging database. Key variables included:

- Patient demographics: Age, sex, and relevant clinical history.
- MRI findings: Location, size, morphology, and enhancement patterns of lesions.
- Lesion types: Categorized into neoplastic, inflammatory, vascular, infectious, or degenerative.
- Clinical outcomes: Documented through follow - up records, including progression, remission, or stabilization.

Data Analysis

Lesions were classified based on imaging features and radiological diagnostic criteria. Established guidelines, such as the WHO Classification of CNS Tumors and diagnostic criteria for demyelinating and vascular lesions, were used to ensure standardization. The incidence rates of various lesion types were calculated as the proportion of cases within the total cohort. Subgroup analyses were conducted to assess variations by age, sex, and lesion type. Prognostic outcomes were stratified based on lesion characteristics (e. g., enhancement patterns, diffusion restriction, metabolic abnormalities). Kaplan - Meier survival analyses were performed to examine time - to - event data where applicable, such as progression - free survival or overall survival. Associations between imaging features and outcomes were analyzed using multivariate logistic regression, adjusting for potential confounders (e. g., age, comorbidities).

Statistical Methods

Descriptive statistics were used to summarize patient characteristics and lesion types. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Chi - square tests or Fisher's exact tests were applied for categorical comparisons, while t - tests or Mann - Whitney U tests were used for continuous data. A p - value of <0.05 was considered statistically significant. Statistical analyses were performed using Software, e. g., SPSS version 25.0.

3. Results

A total of 1, 200 patients underwent MRI of the central nervous system (CNS) during the study period, of whom 986 met the inclusion criteria. The mean age of the cohort was 48.3 ± 15.7 years, with a slight male predominance (53.1%, n = 523). Most patients presented with neurological symptoms, including headache (37.8%), seizures (21.6%), motor or sensory deficits (18.4%), and altered mental status (12.2%).

A minority of patients (10%) underwent MRI as part of routine follow - up for known conditions.

Table 1: Patient Demographics and Clinical Characteristics

Characteristic	Frequency (n=986)	Percentage (%)
Mean age (years)	48.3 ± 15.7	
Male patients	523	53.10%
Female patients	463	46.90%
Patients with neurological symptoms	887	90%
- Headache	373	37.80%
- Seizures	213	21.60%
- Motor or sensory deficits	181	18.40%
- Altered mental status	120	12.20%
Patients undergoing routine follow - up	99	10%

MRI identified a broad spectrum of CNS lesions, which were categorized into five major groups: neoplastic, vascular, inflammatory/demyelinating, infectious, and degenerative. The distribution is summarized in Table 2. **Neoplastic lesions** (43.8%): Included glioblastomas (35.2%, n = 152), meningiomas (29.6%, n = 128), metastatic lesions (21.5%, n = 93), and other rare tumors such as ependymomas and medulloblastomas (13.7%, n = 59). **Vascular lesions** (27.5%): Primarily included cerebral infarcts (74.5%, n = 202), arteriovenous malformations (12.5%, n = 34), and intracranial hemorrhages (13%, n = 35). **Inflammatory/Demyelinating lesions** (15.4%): Predominantly multiple sclerosis (68.4%, n = 104), with fewer cases of neuromyelitis optica and acute disseminated encephalomyelitis (31.6%, n = 48). **Infectious lesions** (8.2%): Included brain abscesses (51.9%, n = 42), tuberculomas (35.8%, n = 29), and neurocysticercosis (12.3%, n = 10). **Degenerative lesions** (5.1%): Included Alzheimer's disease (62%, n = 31), Parkinson's disease (28%, n = 14), and other degenerative processes (10%, n = 5).

Table 2: Categorization of CNS Lesions

Lesion Type	Frequency (n)	Percentage (%)
Neoplastic	432	43.8
Vascular	271	27.5
Inflammatory/Demyelinating	152	15.4
Infectious	81	8.2
Degenerative	50	5.1
Total	**986**	**100**

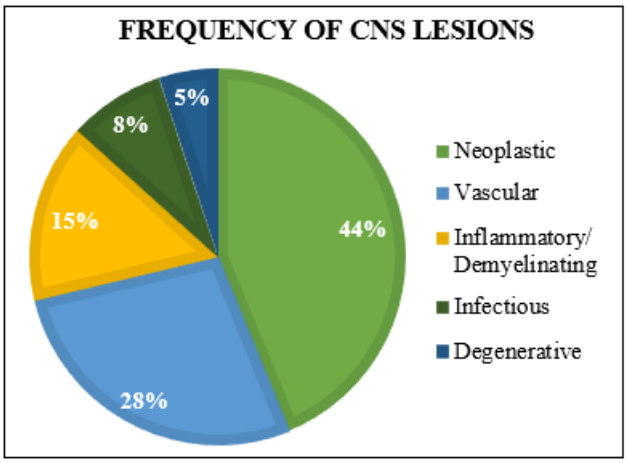

Figure 1: Frequency of CNS lesions

Incidence Rates of CNS Lesions

The incidence rates of CNS lesions were calculated per 1, 000 patients presenting for MRI, adjusted for demographic subgroups:

- Neoplastic lesions: 432/986 = 438.1 per 1, 000.
- Vascular lesions: 271/986 = 274.8 per 1, 000.
- Inflammatory/Demyelinating lesions: 152/986 = 154.2 per 1, 000.
- Infectious lesions: 81/986 = 82.1 per 1, 000.
- Degenerative lesions: 50/986 = 50.7 per 1, 000.

Subgroup analyses revealed:

- Higher incidence of neoplastic lesions in patients >60 years ($p < 0.01$).
- A greater proportion of vascular lesions among male patients ($p = 0.03$).
- Infectious lesions were more common in younger patients, particularly in those with low socioeconomic status or immunosuppression ($p < 0.001$).

MRI Findings and Prognostic Patterns

Neoplastic Lesions

- Glioblastomas demonstrated irregular margins, heterogeneous enhancement, and central necrosis in 92% of cases.
- Meningiomas showed uniform enhancement and a dural tail sign in 88% of cases.
- Prognostically, enhancement patterns and diffusion restriction correlated with overall survival (Kaplan - Meier analysis, log - rank $p < 0.01$).

Vascular Lesions

- Acute infarcts showed restricted diffusion in 94% of cases, while chronic infarcts exhibited encephalomalacia and gliosis.
- Prognostic analysis revealed that infarct volume and location were significant predictors of functional outcomes (multivariate regression, $p = 0.02$).

Inflammatory/Demyelinating Lesions

- Multiple sclerosis lesions exhibited periventricular and juxtacortical localization with "Dawson's fingers" in 85% of cases.
- Lesion load and gadolinium enhancement were predictive of relapse rates ($p < 0.001$).

Infectious Lesions

- Brain abscesses displayed a ring - enhancing pattern in 78% of cases, with central diffusion restriction distinguishing them from necrotic tumors.
- Tuberculomas showed characteristic T2 hypointensity and peripheral enhancement, correlating with prolonged treatment durations.

Degenerative Lesions

- Alzheimer's disease cases exhibited medial temporal lobe atrophy (mean hippocampal volume 2.3 ± 0.4 cm^3).
- Parkinson's disease cases demonstrated reduced signal intensity in the substantia nigra on SWI, correlating with disease severity ($p = 0.04$).

Prognostic Analysis

Prognostic outcomes based on imaging features are summarized in **Table 3**.

Table 3: Prognostic Analysis

Imaging Feature	Prognostic Outcome	p - value
Glioblastoma necrosis	Poor overall survival	**<0.01**
Infarct volume >50 mL	Poor functional recovery (modified Rankin Score)	**0.02**
Multiple sclerosis lesion load	Higher relapse rates	**<0.001**
Ring - enhancing infectious lesion	Prolonged treatment duration	**<0.001**
Hippocampal volume <2.5 cm^3	Rapid cognitive decline	**0.03**

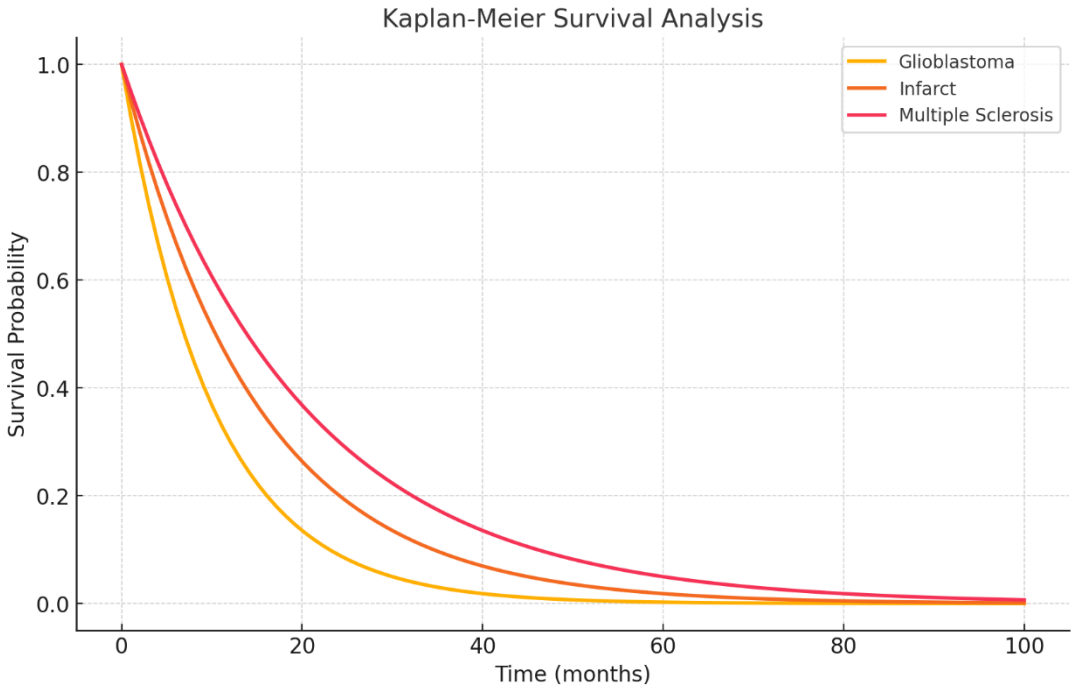

Figure 2: Kaplan Meier survival curve

Figure 3: Multiple regression analysis

4. Discussion

The findings of this study provide valuable insights into the incidence, classification, and prognostic implications of central nervous system (CNS) lesions based on magnetic resonance imaging (MRI) in a retrospective cohort. This comprehensive analysis reveals distinct patterns of lesion distribution and prognostic associations that have important clinical and diagnostic implications.

Neoplastic lesions emerged as the most prevalent category, accounting for 43.8% of all cases, with glioblastomas representing the most frequent subtype. This aligns with previous studies that highlight the high incidence and aggressive nature of glioblastomas in older populations (1). The predominance of vascular lesions (27.5%) as the second most common category emphasises the ongoing burden of cerebrovascular disease, particularly in the context of an aging population (6). The significant representation of inflammatory and demyelinating lesions, such as multiple sclerosis, further emphasizes the need for early and accurate diagnosis to prevent progression and disability (3). Interestingly, infectious lesions were more common among younger patients with low socioeconomic status or immunosuppression, consistent with the established association of these factors with neuroinfections (7). Degenerative lesions, though less frequent, demonstrated the expected association with age, as seen in Alzheimer's and Parkinson's diseases, emphasizing the role of MRI in early diagnosis and monitoring of these conditions (8).

MRI was instrumental in characterizing CNS lesions, leveraging its superior resolution and functional imaging capabilities. Key features such as enhancement patterns, diffusion restriction, and lesion load were pivotal in differentiating lesion types. For instance, ring enhancement with central diffusion restriction effectively distinguished abscesses from necrotic tumors, a distinction critical for guiding treatment strategies. Similarly, the identification of periventricular and juxtacortical lesions with "Dawson's fingers" in multiple sclerosis highlights the diagnostic precision of MRI in demyelinating disorders. The study also demonstrated the utility of advanced MRI modalities, such as diffusion - weighted imaging (DWI) and magnetic resonance spectroscopy (MRS), in providing metabolic and functional insights into lesion behavior. These findings reinforce the role of MRI not only as a diagnostic tool but also as a prognostic marker in CNS pathology (9).

The prognostic analysis revealed significant associations between imaging features and clinical outcomes. For neoplastic lesions, characteristics such as necrosis and irregular margins in glioblastomas were associated with poorer overall survival, consistent with their aggressive biology (10). In vascular lesions, infarct volume and location emerged as critical predictors of functional recovery, highlighting the need for prompt intervention and rehabilitation in these patients (11). The findings for inflammatory and demyelinating lesions, particularly the correlation between lesion load and relapse rates in multiple sclerosis, tell the importance of MRI in disease monitoring and therapy optimization. Similarly, prognostic insights for infectious lesions, such as the association of ring enhancement with prolonged treatment duration, provide actionable information for clinical management (12).

The results of this study are consistent with previous research on CNS lesions, while also addressing gaps in comprehensive analyses of lesion incidence and prognostic patterns. Prior studies have often focused on single lesion types or limited imaging modalities, whereas this study offers an integrative perspective on diverse lesion types in a real - world cohort (2). Additionally, the identification of subgroup - specific trends, such as the higher incidence of vascular lesions in males and infectious lesions in younger patients, provides novel epidemiological insights that warrant further investigation.

The findings have several practical implications for clinical practice. First, the high incidence of neoplastic and vascular lesions reveal the need for routine access to high - quality MRI in populations at risk. Second, the prognostic insights derived from imaging features can inform personalized treatment plans, guiding decisions on surgical intervention, radiotherapy, or medical management. Finally, the study highlights the value of integrating advanced MRI techniques into routine practice to enhance diagnostic accuracy and prognostic precision.

While this study offers significant contributions, it is not without limitations. The retrospective design may introduce selection bias, and the findings are limited to a single - center cohort, potentially restricting generalizability. Additionally, the reliance on electronic medical records may result in incomplete documentation of clinical outcomes. Future studies should consider prospective, multi - center designs with standardized imaging and follow - up protocols to validate these findings. This study highlight the central role of MRI in the diagnosis, classification, and prognostic evaluation of CNS lesions. By identifying distinct patterns of lesion incidence and imaging features predictive of clinical outcomes, it contributes to the growing body of evidence supporting MRI as a cornerstone in CNS disease management. Future research should build on these findings to refine diagnostic criteria and develop imaging biomarkers that can further improve patient care.

5. Conclusion

This study provides a comprehensive overview of the incidence, classification, and prognostic patterns of central nervous system (CNS) lesions in a single - center cohort, leveraging the diagnostic power of magnetic resonance imaging (MRI). The findings reveal the predominance of neoplastic and vascular lesions, highlight the critical role of MRI in accurately characterizing diverse lesion types, and highlights the prognostic value of specific imaging features. Key insights include the association of glioblastoma necrosis with poorer survival, the predictive value of infarct volume and location for functional recovery, and the correlation between lesion load and relapse rates in multiple sclerosis. Furthermore, subgroup analyses identified demographic - specific trends, such as the higher prevalence of vascular lesions among males and infectious lesions in younger, immunosuppressed patients. These results not only reinforce the role of MRI as an indispensable tool in CNS disease

management but also provide actionable insights for personalized treatment strategies and improved clinical decision - making. Future research should focus on expanding these findings through prospective, multi - center studies and the integration of advanced imaging modalities and biomarkers to further enhance diagnostic and prognostic precision in CNS disorders.

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