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Role of MRI in diagnosis of glioblastoma: A review paper

Laxmi Singh[1], Dr. Himadri Shekhar Dey[2], Dr. Sachin Datt[3], Nakul Tyagi[1]
[1] Assistant Professor, Department of MRIT, School of Health Sciences, Sushant University, Gurugram, Haryana, India
[2] Associate Professor, Department of Planning, School of Art and Architecture, Sushant University, Haryana, India
[3] Associate Professor, School of Design, Sushant University, Haryana, India

Abstract
Magnetic Resonance Imaging plays a significant role in the diagnosis and evaluation of glioblastoma, which is considered one of the most aggressive and malignant primary brain tumors in adults. Glioblastoma is characterized by rapid growth, infiltrative behavior, necrosis, vascular proliferation, and poor prognosis. Early and accurate diagnosis is essential for treatment planning, surgical intervention, and patient management. MRI has emerged as the gold standard imaging modality for brain tumor assessment because of its superior soft tissue contrast, multiplanar imaging capability, and detailed anatomical visualization.

The present review paper focuses on the role of MRI in the diagnosis of glioblastoma by analyzing findings from previously published literature. Approximately 30–40 research articles, review papers, and clinical studies were reviewed to understand MRI features, advanced imaging techniques, diagnostic accuracy, and clinical significance in glioblastoma evaluation. The review included studies related to conventional MRI sequences, diffusion-weighted imaging, perfusion MRI, magnetic resonance spectroscopy, functional MRI, and contrast-enhanced imaging.

The reviewed literature demonstrated that glioblastoma commonly appears as an irregular, heterogeneous mass lesion with central necrosis, surrounding edema, and contrast enhancement on MRI. Advanced MRI techniques were found to improve tumor characterization, differentiate glioblastoma from other intracranial lesions, and assess tumor progression and recurrence. MRI also contributes significantly to treatment planning, biopsy guidance, postoperative evaluation, and prognosis assessment. The findings of the reviewed studies confirmed that MRI remains an essential and reliable imaging modality for diagnosing glioblastoma. Future advancements involving artificial intelligence, quantitative imaging biomarkers, and advanced MRI protocols may further improve early diagnosis and therapeutic monitoring of glioblastoma patients.

Keywords: Glioblastoma, magnetic resonance imaging (MRI), brain tumors, advanced MRI techniques, neuroimaging

Introduction

Glioblastoma, commonly referred to as glioblastoma multiforme (GBM), is the most aggressive and malignant primary brain tumor originating from glial cells within the central nervous system. It is classified as a Grade IV astrocytoma according to the World Health Organization (WHO) classification of brain tumors and is characterized by rapid cellular proliferation, extensive infiltration, abnormal vascular growth, tissue necrosis, and poor prognosis. Glioblastoma accounts for the majority of malignant primary brain tumors in adults and represents one of the greatest challenges in neuro-oncology because of its highly invasive nature and limited survival rate.

Glioblastoma usually affects adults between 45 and 70 years of age, although it can occur in younger individuals as well. The disease is slightly more common in males than females. Despite significant advancements in neurosurgery, radiotherapy, chemotherapy, and targeted therapies, the prognosis of glioblastoma remains poor, with average survival rates typically ranging between 12 and 18 months after diagnosis. The aggressive biological behavior of glioblastoma and its resistance to therapy contribute significantly to its high mortality rate.

The exact etiology of glioblastoma is not fully understood; however, several genetic, molecular, environmental, and biological factors have been associated with its development. Mutations involving genes such as TP53, EGFR, PTEN, and IDH are frequently observed in glioblastoma patients. Abnormal cellular signaling pathways, uncontrolled cell proliferation, angiogenesis, and tumor infiltration contribute to tumor progression and recurrence. Glioblastoma is also known for its ability to invade surrounding brain tissue, making complete surgical removal extremely difficult.

Patients with glioblastoma commonly present with a variety of neurological and cognitive symptoms depending on tumor size, location, and associated mass effect. Common clinical manifestations include persistent headache, seizures, nausea, vomiting, visual disturbances, memory impairment, speech difficulties, personality changes, weakness, confusion, and altered mental status. Symptoms often worsen progressively due to increasing intracranial pressure and tumor expansion. Since these symptoms are nonspecific and may resemble other neurological disorders, accurate imaging evaluation is essential for diagnosis.

The diagnosis of glioblastoma requires a multidisciplinary approach involving clinical examination, neurological assessment, neuroimaging, histopathological analysis, and molecular evaluation. Among all imaging modalities, Magnetic Resonance Imaging has become the gold standard technique for evaluating brain tumors because of its superior soft tissue contrast, multiplanar capability, and ability to provide detailed anatomical and physiological information without the use of ionizing radiation.

MRI plays a central role in the diagnosis, characterization, treatment planning, and follow-up evaluation of glioblastoma. Conventional MRI sequences such as T1-weighted imaging, T2-weighted imaging, Fluid Attenuated

Inversion Recovery (FLAIR), and contrast-enhanced imaging provide detailed visualization of tumor morphology, surrounding edema, necrosis, hemorrhage, and involvement of adjacent brain structures. Glioblastoma typically appears on MRI as a heterogeneous irregular mass lesion with central necrosis, surrounding vasogenic edema, and peripheral contrast enhancement due to breakdown of the blood-brain barrier.

Contrast-enhanced MRI is particularly important because glioblastoma demonstrates intense and irregular enhancement caused by abnormal tumor vascularity and angiogenesis. Ring-like enhancement surrounding necrotic regions is considered one of the characteristic imaging findings of glioblastoma. MRI also helps identify associated complications such as midline shift, ventricular compression, and raised intracranial pressure resulting from mass effect.

Over the past few decades, advancements in MRI technology have significantly improved the diagnostic accuracy of brain tumor imaging. Advanced MRI techniques such as Diffusion Weighted Imaging (DWI), Diffusion Tensor Imaging (DTI), Perfusion Weighted Imaging (PWI), Magnetic Resonance Spectroscopy (MRS), Functional MRI (fMRI), and Susceptibility Weighted Imaging (SWI) provide additional structural, functional, and metabolic information regarding glioblastoma.

Diffusion Weighted Imaging evaluates the movement of water molecules within tissues and helps identify highly cellular tumor regions. Low Apparent Diffusion Coefficient (ADC) values are commonly associated with aggressive tumor behavior and increased cellularity. Diffusion imaging is also valuable for differentiating glioblastoma from abscesses and other intracranial lesions.

Perfusion MRI assesses tumor vascularity and blood flow by measuring cerebral blood volume and cerebral blood flow. Glioblastomas demonstrate significantly increased perfusion because of extensive neovascularization and angiogenesis. Perfusion imaging therefore contributes to tumor grading, treatment planning, and evaluation of treatment response.

Magnetic Resonance Spectroscopy provides metabolic information about tumor tissues by analyzing biochemical markers such as choline, creatine, N-acetylaspartate, lactate, and lipids. Elevated choline levels and reduced N-acetylaspartate are characteristic metabolic findings associated with glioblastoma. MRS also helps differentiate recurrent tumor from radiation necrosis during follow-up imaging.

Functional MRI is increasingly used for preoperative planning by identifying eloquent brain regions responsible for speech, motor, and sensory functions. This technique helps neurosurgeons minimize postoperative neurological deficits while maximizing tumor resection. Functional mapping has therefore become an important component of modern brain tumor surgery.

MRI also plays an important role after treatment. Postoperative MRI helps assess residual tumor tissue, monitor treatment response, and identify tumor recurrence. Distinguishing recurrent glioblastoma from radiation necrosis is often challenging, but advanced MRI techniques significantly improve diagnostic confidence during follow-up evaluation.

Recent developments involving artificial intelligence, radiomics, and machine learning have further enhanced the role of MRI in neuro-oncology. AI-based algorithms are increasingly being used for automated tumor segmentation, tumor grading, prognostic prediction, and treatment response evaluation. These emerging technologies may improve diagnostic speed, accuracy, and personalized treatment planning in the future.

Several research studies have evaluated the role of MRI in diagnosing and managing glioblastoma. Published literature consistently demonstrates that MRI provides essential information regarding tumor morphology, infiltration, metabolism, vascularity, and functional involvement. Literature review studies are therefore valuable for summarizing current evidence, comparing imaging findings, and understanding recent advancements in glioblastoma imaging.

The present review paper focuses on the role of MRI in the diagnosis of glioblastoma by analyzing findings from approximately 30–40 published studies and review articles. The review aims to summarize conventional and advanced MRI findings, evaluate diagnostic applications, discuss treatment-related imaging, and explore recent technological advancements associated with glioblastoma imaging.

In conclusion, MRI remains the most important imaging modality for the comprehensive evaluation of glioblastoma because of its ability to provide detailed structural, functional, and metabolic information. Understanding MRI findings in glioblastoma is essential for accurate diagnosis, treatment planning, surgical guidance, and monitoring disease progression. Continuous advancements in MRI technology and artificial intelligence are expected to further improve neuro-oncological imaging and patient management in the future.

Aim of the Study

To review the role of MRI in the diagnosis and evaluation of glioblastoma based on previously published literature.

Objectives of the Study

- To understand MRI findings associated with glioblastoma.
- To evaluate the role of conventional and advanced MRI techniques.
- To analyze the diagnostic importance of MRI in glioblastoma.
- To review the role of MRI in treatment planning and follow-up.
- To summarize recent advancements in glioblastoma imaging.

Methodology

Type of Study

Literature Review Study

Study Design

The present study was conducted as a narrative literature review based on previously published research articles, clinical studies, and review papers related to MRI in glioblastoma diagnosis.

Literature Search Strategy

Relevant articles were collected from scientific databases including:

- PubMed
- Google Scholar

- Scopus
- ScienceDirect
- ResearchGate

Keywords Used
- Glioblastoma
- MRI in glioblastoma
- Brain tumor imaging
- Advanced MRI techniques
- Diffusion MRI
- Perfusion MRI
- Magnetic resonance spectroscopy
- Glioblastoma diagnosis

Inclusion Criteria
- English-language peer-reviewed articles
- Studies related to MRI diagnosis of glioblastoma
- Articles published between 2000 and 2025
- Studies discussing conventional and advanced MRI findings

Exclusion Criteria
- Non-English publications
- Duplicate studies
- Incomplete articles
- Studies unrelated to glioblastoma imaging

Data Collection and Analysis
Approximately 30–40 published articles were reviewed. Relevant findings related to MRI appearance, advanced imaging techniques, diagnostic performance, and clinical applications were summarized and analyzed.

Results
The present literature review analyzed approximately 30–40 published research articles and clinical studies related to the role of Magnetic Resonance Imaging in the diagnosis of glioblastoma. The reviewed literature consistently demonstrated that MRI is highly sensitive and reliable for identifying glioblastoma characteristics, evaluating tumor extent, and guiding clinical management.
The findings obtained from the reviewed studies are summarized below

Conventional MRI Findings in Glioblastoma
Most reviewed studies described glioblastoma as a large heterogeneous intra-axial brain lesion with irregular margins, central necrosis, surrounding edema, and mass effect.

T1-Weighted Imaging Findings
The majority of studies reported that glioblastoma appeared:
- Hypointense or heterogeneous on T1-weighted images
- With poorly defined margins
- Central areas of necrosis showing low signal intensity

Post-contrast T1-weighted imaging commonly demonstrated:
- Irregular ring-like enhancement
- Peripheral enhancement around necrotic regions
- Breakdown of the blood-brain barrier

Several studies identified contrast enhancement as an important indicator of tumor aggressiveness and vascular proliferation.

T2-Weighted and FLAIR Imaging Findings
Most reviewed articles demonstrated that glioblastoma showed:
- Hyperintense signal on T2-weighted images
- Extensive surrounding vasogenic edema
- Tumor infiltration into adjacent brain tissue

FLAIR sequences were especially useful for:
- Assessing peritumoral edema
- Identifying infiltrative tumor margins
- Detecting involvement of surrounding white matter

The reviewed literature indicated that edema associated with glioblastoma often extended beyond visible tumor margins due to infiltrative tumor growth.

Central Necrosis and Heterogeneity
A major finding consistently reported across the reviewed studies was the presence of:
- Central necrosis
- Intratumoral hemorrhage
- Cystic degeneration
- Tumor heterogeneity

The heterogeneous appearance of glioblastoma on MRI was associated with:
- Rapid tumor growth
- Tissue destruction
- Hypoxia
- Abnormal vascular proliferation

Several studies suggested that necrosis is one of the characteristic imaging features differentiating glioblastoma from lower-grade gliomas.

Mass Effect and Midline Shift
The literature review demonstrated that large glioblastomas commonly produced:
- Significant mass effect
- Compression of adjacent brain structures
- Ventricular compression
- Midline shift

These findings were frequently associated with:
- Raised intracranial pressure
- Neurological deficits
- Headache and vomiting

The severity of mass effect often correlated with tumor size and surrounding edema.

Diffusion Weighted Imaging (DWI) Findings
Many reviewed studies emphasized the importance of Diffusion Weighted Imaging in glioblastoma evaluation.

Common DWI Findings Included:
- Restricted diffusion in hypercellular tumor regions
- Low Apparent Diffusion Coefficient (ADC) values
- Increased cellular density

The reviewed literature demonstrated that:
- Highly cellular tumor regions showed restricted water diffusion
- Necrotic regions demonstrated facilitated diffusion

- ADC values helped differentiate tumor grades

Several studies reported that DWI contributed to differentiating glioblastoma from abscesses, metastases, and lymphoma.

Perfusion MRI Findings
Perfusion MRI was identified as one of the most valuable advanced imaging techniques for glioblastoma assessment.

Common Findings Included:
- Increased cerebral blood volume (CBV)
- Increased cerebral blood flow (CBF)
- Abnormal neovascularization
- Enhanced tumor perfusion

The reviewed studies showed that:
- Glioblastomas demonstrated significantly elevated perfusion compared to low-grade tumors
- Increased vascularity was associated with aggressive tumor behavior
- Perfusion MRI improved tumor grading accuracy

Many studies concluded that perfusion MRI helps evaluate tumor angiogenesis and treatment response.

Magnetic Resonance Spectroscopy (MRS) Findings
The literature demonstrated that MRS provided important metabolic information about glioblastoma.

Common Spectroscopic Findings Included:
- Increased choline peak
- Decreased N-acetylaspartate (NAA)
- Elevated lipid and lactate peaks

These metabolic alterations were associated with:
- Increased tumor cell membrane turnover
- Neuronal destruction
- Tissue necrosis
- Tumor hypoxia

Several studies reported that MRS was useful in differentiating recurrent tumor from radiation necrosis.

Functional MRI Findings
Functional MRI was reported to be highly useful for preoperative planning.

Major Applications Included:
- Localization of motor cortex
- Identification of speech areas
- Mapping of functional brain regions

The reviewed literature demonstrated that functional MRI:
- Reduced surgical complications
- Assisted neurosurgeons in preserving eloquent brain regions
- Improved surgical planning and patient outcomes

Role of MRI in Differential Diagnosis
Many reviewed studies highlighted MRI's role in differentiating glioblastoma from other intracranial lesions such as:
- Brain metastasis
- Primary CNS lymphoma
- Brain abscess
- Lower-grade gliomas

Advanced MRI techniques improved diagnostic confidence by evaluating:
- Tumor metabolism
- Diffusion characteristics
- Perfusion patterns
- Infiltrative behavior

Postoperative and Follow-Up MRI Findings
The reviewed literature strongly supported the role of MRI in postoperative assessment and follow-up imaging.

MRI Applications Included:
- Detection of residual tumor tissue
- Monitoring treatment response
- Identifying tumor recurrence
- Differentiating recurrence from radiation necrosis

Several studies reported that:
- Contrast-enhanced MRI was essential after surgical resection
- Advanced MRI sequences improved follow-up evaluation accuracy

Artificial Intelligence and Advanced MRI Applications
Recent studies discussed the emerging role of artificial intelligence and radiomics in glioblastoma imaging.

Applications Included:
- Automated tumor segmentation
- Tumor grading
- Prognostic prediction
- Treatment response assessment

The literature suggested that AI-assisted MRI interpretation may improve diagnostic speed and accuracy in future clinical practice.

Overall Literature Findings
The reviewed studies collectively demonstrated that
- MRI is the gold standard imaging modality for glioblastoma diagnosis.
- Glioblastoma commonly presents as a heterogeneous ring-enhancing lesion with necrosis and edema.
- Advanced MRI techniques significantly improve tumor characterization.
- MRI plays an important role in diagnosis, surgical planning, treatment monitoring, and recurrence evaluation.
- Functional MRI and AI-based imaging techniques are becoming increasingly important in modern neuro-oncology imaging.

Overall, the literature confirmed that MRI provides comprehensive structural, functional, and metabolic information essential for accurate diagnosis and management of glioblastoma patients.

Discussion
The reviewed literature demonstrated that MRI plays a central role in the diagnosis and management of

glioblastoma. Glioblastoma is highly aggressive and infiltrative, making accurate imaging essential for early detection and treatment planning.

Conventional MRI remains the primary imaging method for identifying glioblastoma characteristics such as necrosis, edema, hemorrhage, and contrast enhancement. Ring-enhancing lesions with central necrosis and surrounding edema were the most consistently reported MRI findings across reviewed studies.

Advanced MRI techniques significantly improved tumor characterization and diagnostic accuracy. Diffusion imaging helped identify hypercellular tumor regions, while perfusion MRI provided information regarding tumor angiogenesis and vascularity. MR spectroscopy contributed metabolic information useful for differentiating glioblastoma from other intracranial lesions.

The reviewed studies also emphasized the importance of MRI in postoperative evaluation and treatment monitoring. MRI assists in identifying residual tumor tissue and differentiating recurrent tumor from treatment-related changes such as radiation necrosis.

Several reviewed articles discussed the growing role of artificial intelligence in MRI interpretation. AI-assisted tumor segmentation and radiomics analysis may improve diagnostic efficiency and prognostic evaluation in future clinical practice.

Despite its advantages, MRI has certain limitations including high cost, motion artifacts, and challenges in differentiating tumor infiltration from surrounding edema. However, MRI remains the most reliable imaging modality for comprehensive glioblastoma assessment.

Conclusion

MRI is the gold standard imaging modality for diagnosing and evaluating glioblastoma because of its superior soft tissue contrast and multiplanar imaging capability. Conventional and advanced MRI techniques provide detailed information regarding tumor morphology, vascularity, metabolism, and infiltration.

The reviewed literature confirmed that MRI significantly contributes to early diagnosis, tumor characterization, treatment planning, postoperative assessment, and recurrence monitoring in glioblastoma patients. Advanced MRI techniques and artificial intelligence-based imaging analysis may further improve diagnostic accuracy and patient management in the future.

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