



Article

# Current Advances in Brain Mri for The Diagnosis of Glioblastoma: the Role of Tractography and Mr Spectroscopy

Alisher Ibromkhimov Arslonboy o'g'li<sup>1</sup>

Otabek Vakhobovich Ablyazov<sup>2</sup>

<sup>1,2</sup> Tashkent State Medical University, Tashkent, Uzbekistan

\* Correspondence: -

**Abstract:** Dental Glioblastoma (GBM) is the most aggressive primary brain tumor in adults, characterized by rapid infiltrative growth, a poor prognosis, and a high rate of recurrence. Magnetic resonance imaging (MRI) remains the gold standard for non-invasive diagnosis, treatment planning, and postoperative monitoring of GBM. This review examines current advances in MRI-based neuroimaging of glioblastoma, with emphasis on tractography, magnetic resonance spectroscopy (MRS), perfusion imaging, automated segmentation, deep learning-assisted diagnosis, and intraoperative MRI. A synthesis of recent literature demonstrates that multiparametric and advanced MRI techniques substantially improve diagnostic accuracy, facilitate safer maximal surgical resection, and support the differentiation of tumor progression from treatment-related changes, thereby contributing to improved patient outcomes.

**Keywords:** glioblastoma, MRI, tractography, magnetic resonance spectroscopy, neuroimaging, brain tumors, speckle tracking, deep learning, perfusion imaging, intraoperative MRI.

## 1. INTRODUCTION

Glioblastoma (GBM) is the most common and most rapidly progressive primary malignant tumor of the central nervous system in adults. The tumor predominantly affects the frontal and temporal lobes, though it may involve any region of the brain. GBM is characterized by rapid infiltrative growth, pronounced invasiveness, and the capacity to spread into surrounding cerebral tissues, which substantially complicates complete surgical resection [1].

Despite significant advances in neurosurgery, radiotherapy, and pharmacotherapy, GBM remains associated with extremely poor overall survival and a high frequency of recurrence. Median survival following standard-of-care treatment — maximal safe resection followed by concurrent chemoradiation with temozolomide — remains approximately 14–16 months. The complexity of treatment is compounded by an incomplete understanding of risk factors and the intricate molecular-biological mechanisms underlying tumorigenesis, making the development of more effective diagnostic and therapeutic strategies one of the foremost challenges in contemporary neuro-oncology.

In clinical practice, MRI has established itself as the gold standard and primary non-invasive imaging modality for the radiological characterization of GBM. It is widely applied not only in initial tumor detection and differential diagnosis, but also plays a

**Citation:** Arslonboy o'g'li A. I. Current Advances in Brain Mri for The Diagnosis of Glioblastoma: the Role of Tractography and Mr Spectroscopy. Central Asian Journal of Medical and Natural Science 2026, 7(3), 557-582.

Received: 10<sup>th</sup> Mar 2026

Revised: 11<sup>th</sup> Apr 2026

Accepted: 14<sup>th</sup> May 2026

Published: 16<sup>th</sup> Jun 2026



**Copyright:** © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license

(<https://creativecommons.org/licenses/by/4.0/>)

pivotal role in treatment planning, intraoperative guidance, and long-term post-treatment monitoring [2]. The objective of this review is to systematically evaluate the current capabilities of advanced MRI techniques – including diffusion tensor imaging (DTI) and tractography, magnetic resonance spectroscopy (MRS), perfusion imaging, automated segmentation, deep learning-assisted detection, and intraoperative MRI – in the diagnosis and management of glioblastoma.

## **2. METHODS**

A narrative review of the published literature was conducted. Systematic searches of PubMed/MEDLINE, Scopus, and Google Scholar databases were performed for publications from 2014 to 2025, using the following search terms: "glioblastoma MRI," "tractography glioma," "MR spectroscopy brain tumor," "perfusion MRI glioblastoma," "automated segmentation glioblastoma," "deep learning brain tumor MRI," "intraoperative MRI glioma," and "immunotherapy neuroimaging." Only peer-reviewed original articles, systematic reviews, meta-analyses, and expert consensus publications in English were included. Studies focused exclusively on non-MRI modalities or non-GBM tumor types without comparative data were excluded. Fifteen sources were selected based on their direct relevance to the review objectives and methodological quality. Each reference is cited only once at the point most pertinent to the discussion.

## **3. RESULTS**

### **3.1. Conventional MRI and General Diagnostic Role**

Advanced MRI techniques are capable of providing increasingly detailed, high-resolution information about tumor structure, biological characteristics, vascularity, and patterns of local and distant spread. However, the accurate assessment of treatment efficacy remains one of the most complex and challenging tasks in modern neuro-oncology. These diagnostic difficulties stem primarily from the need to reliably differentiate true tumor progression from the broad spectrum of post-treatment effects – including pseudoprogression following radiotherapy and chemotherapy – that may closely mimic recurrence on standard imaging [3].

Epidemiological and imaging-based analyses of GBM have highlighted the importance of systematic radiological characterization at diagnosis. Standardized MRI-based classification of tumor features – including localization, enhancement patterns, and necrotic core delineation – provides foundational data for prognosis stratification and treatment response assessment [4].

### **3.2. MRI-Defined Infiltration Patterns and Survival**

A significant correlation has been identified between MRI-defined infiltration patterns and survival outcomes in patients with GBM. Certain GBM subtypes exhibit more aggressive and diffusely infiltrative growth, associated with reduced overall survival and poorer clinical prognosis. These findings underscore the prognostic relevance of systematically classifying MRI-based infiltration patterns. To validate these observations and establish reproducible predictive models, prospective studies in large, well-characterized patient cohorts employing standardized automated computational classification methods are required [5].

### **3.3. Differential Diagnosis: GBM vs. Primary CNS Lymphoma**

MRI has demonstrated high diagnostic efficiency in differentiating primary central nervous system (CNS) lymphoma from glioblastoma. In particular, advanced techniques incorporating dynamic susceptibility contrast (DSC) perfusion imaging or arterial spin labeling (ASL) provide strong and reliable diagnostic performance in this differential diagnosis. A systematic review and meta-analysis confirmed that MRI sequences employing DSC or ASL represent a valuable, non-invasive diagnostic tool for improving differential accuracy in clinical settings [6].

### **3.4. Automated Segmentation of GBM on MRI**

Automated segmentation of glioblastoma from MRI data is typically performed using multiple sequences, including T1-weighted, contrast-enhanced T1-weighted, T2-weighted, and FLAIR images. However, the use of a large number of input modalities may introduce redundant information, reducing the efficiency of automated analysis algorithms. Moreover, a greater number of required sequences increases the risk of missing data in clinical practice, which may adversely affect the accuracy and reliability of diagnostic models. Investigations into modality redundancy have therefore focused on identifying the minimal set of MRI sequences that preserves segmentation performance [7].

### **3.5. Deep Learning for GBM Detection and Classification**

The integration of multiparametric MRI sequences with advanced deep learning architectures enables highly effective preoperative detection of GBM and solitary brain metastases. Among the evaluated models, the 3D ResNet-18 architecture demonstrated the highest diagnostic performance for both tumor types, achieving superior sensitivity and specificity. These results confirm the strong clinical potential of deep learning-assisted neuroimaging and support its future integration into computer-assisted diagnostic systems for neuro-oncology [8].

### **3.6. Advanced MRI Techniques: Tractography, MRS, and Perfusion**

Advanced MRI modalities have substantially expanded the diagnostic and therapeutic value of neuroimaging in GBM. Diffusion tensor imaging (DTI) and fiber tractography enable visualization of white matter tracts displaced or infiltrated by tumor, providing critical information for preoperative neurosurgical planning and the preservation of eloquent cortex and subcortical pathways. Magnetic resonance spectroscopy (MRS) allows non-invasive in vivo analysis of tumor metabolite profiles — including choline, N-acetyl aspartate, creatine, and lactate — which reflect cellular proliferation, neuronal integrity, and necrosis. Perfusion-weighted imaging (PWI) quantifies tumor microvasculature and angiogenesis, supporting the differentiation of high-grade from low-grade gliomas and the detection of pseudoprogression following chemoradiation. The combined application of these techniques provides a comprehensive multiparametric characterization of GBM that exceeds the diagnostic capacity of any single modality [9].

### **3.7. Intraoperative MRI in GBM Surgery**

To maximize the extent of resection (EOR) in GBM — a factor independently associated with improved overall survival — a range of intraoperative adjunct technologies has been integrated into modern neurosurgical practice. Intraoperative MRI (iMRI) has been repeatedly analyzed as a key modality for improving surgical precision and optimizing resection rates. A single-surgeon observational cohort study confirmed that iMRI in newly diagnosed GBM resection led to significant increases in EOR and residual tumor detection, supporting its role in the intraoperative surgical workflow [10].

The broader landscape of modern glioma surgery has evolved around the principle of safe maximal resection. Alongside iMRI, technologies such as cortical and subcortical mapping with electrical stimulation, functional neuronavigation, intraoperative ultrasound, neuroendoscopy, and fluorescence-guided resection with 5-aminolevulinic acid (5-ALA) have been developed to improve tumor identification while preserving functionally important brain tissue. A comprehensive review of these adjunct surgical technologies underlines that their integration into neurosurgical practice provides measurable intraoperative benefits, although the magnitude of long-term survival advantage attributable to each individual technology requires further prospective evaluation [11].

An observational analysis of the specific role of iMRI in improving EOR and patient survival confirmed that its systematic use in GBM surgery is associated with a higher rate of complete or near-complete tumor removal. These findings support the continued implementation and further refinement of iMRI protocols in dedicated neuro-oncological surgical centers [12].

### 3.8. MRI in the Era of Immunotherapy

With the introduction of immunomodulatory therapies for brain tumors, neuroimaging faces new and significant challenges. Standard gadolinium-enhanced MRI and 18F-FDG positron emission tomography (PET) are relatively non-specific for distinguishing true tumor progression from immunotherapy-related inflammatory changes. The main diagnostic challenges include the need for individualized treatment monitoring strategies and the definition of objective response criteria in the context of rapidly evolving knowledge of neuroinflammatory tumor biology. The development of more specific imaging biomarkers – including advanced MRI and PET-based parameters – is therefore a critical priority for the neuro-oncology imaging community [13].

## 4. DISCUSSION

The results of this review demonstrate that advanced MRI techniques collectively constitute a powerful, non-invasive diagnostic and monitoring framework for glioblastoma. Conventional MRI with gadolinium enhancement remains indispensable for initial tumor detection, delineation, and postoperative surveillance. However, its limitations in characterizing tumor biology and distinguishing treatment-related changes from true progression necessitate the complementary use of advanced multiparametric techniques.

DTI-based tractography and MRS provide unique functional and metabolic information that enhances both preoperative neurosurgical planning and longitudinal assessment of tumor response. The integration of these modalities into standardized multiparametric MRI protocols represents a meaningful step toward more comprehensive and reproducible GBM evaluation. Similarly, perfusion imaging – particularly DSC and ASL sequences – contributes significantly to the differential diagnosis of GBM from CNS lymphoma and to the assessment of angiogenic activity, with meta-analytic evidence supporting its diagnostic reliability.

Automated segmentation and deep learning-based analysis of multiparametric MRI data hold considerable promise for standardizing and accelerating GBM characterization at scale. The 3D ResNet-18 architecture's demonstrated superiority across multicentre datasets reflects a broader trend toward AI-assisted neuro-oncological imaging. Nonetheless, the challenges of modality redundancy and missing data in real-world clinical settings necessitate continued research into optimized, streamlined input protocols for automated systems.

Intraoperative MRI remains among the most clinically impactful advanced technologies in GBM surgery, enabling real-time assessment of resection completeness and reducing the rate of residual enhancing tumor [14]. Its combined use with functional neuronavigation, electrophysiological mapping, and fluorescence guidance reflects the paradigm shift toward multimodal, maximally safe resection strategies.

In the emerging immunotherapy era, the limitations of conventional imaging are increasingly apparent. The development and validation of advanced imaging biomarkers for treatment response assessment and the differentiation of pseudoprogression from tumor growth represent urgent unmet needs [15]. Future research should prioritize the prospective validation of multiparametric MRI-based predictive models – including infiltration pattern classifiers – and the standardization of AI-assisted segmentation pipelines across institutions and imaging platforms.

## 5. CONCLUSION

Modern MRI represents the cornerstone of glioblastoma diagnosis, treatment planning, and long-term monitoring. The integration of advanced neuroimaging modalities – including DTI and tractography, MR spectroscopy, perfusion imaging, automated segmentation, deep learning-assisted detection, and intraoperative MRI – substantially

enhances diagnostic accuracy, supports safer and more complete surgical resection, and improves the differentiation of tumor progression from treatment-related changes.

Continued development and clinical validation of these technologies, including the standardization of AI-based segmentation algorithms, the establishment of multiparametric imaging protocols, and the development of immunotherapy-specific imaging biomarkers, are essential priorities for improving outcomes in patients with glioblastoma. Multicenter prospective studies are needed to translate the promising results of advanced neuroimaging research into routine clinical practice.

## REFERENCES

1. J. Madour, J. Bessette, J. Z. Gu, E. L. Thayer, H. Elinzano, and A. J. Sax, "Glioblastoma: Epidemiology and imaging-based review," *Rhode Island Medical Journal*, vol. 108, no. 8, pp. 50–56, 2025.
2. G. Shukla, G. S. Alexander, S. Bakas, R. Nikam, K. Talekar, J. D. Palmer, and W. Shi, "Advanced magnetic resonance imaging in glioblastoma: a review," *Chinese Clinical Oncology*, vol. 6, no. 4, p. 40, 2017, doi: 10.21037/cco.2017.06.28.
3. F. G. Gonçalves, S. Chawla, and S. Mohan, "Emerging MRI techniques to redefine treatment response in patients with glioblastoma," *Journal of Magnetic Resonance Imaging*, vol. 52, no. 4, pp. 978–997, 2020, doi: 10.1002/jmri.27105.
4. K. Scheu et al., "MRI-defined patterns of infiltration and outcome in patients with glioblastoma," *Neuro-Oncology Advances*, vol. 7, no. 1, p. vdaf114, 2025, doi: 10.1093/oaajnl/vdaf114.
5. S. De Sutter, J. Wuts, W. Geens, A. M. Vanbinst, J. Duerinck, and J. Vandemeulebroucke, "Modality redundancy for MRI-based glioblastoma segmentation," *International Journal of Computer Assisted Radiology and Surgery*, vol. 19, no. 10, pp. 2101–2109, 2024, doi: 10.1007/s11548-024-03238-4.
6. C. H. Suh, H. S. Kim, S. C. Jung, J. E. Park, C. G. Choi, and S. J. Kim, "MRI as a diagnostic biomarker for differentiating primary central nervous system lymphoma from glioblastoma: A systematic review and meta-analysis," *Journal of Magnetic Resonance Imaging*, vol. 50, no. 2, pp. 560–572, 2019, doi: 10.1002/jmri.26602.
7. C. Kong, D. Yan, K. Liu, Y. Yin, and C. Ma, "Multiple deep learning models based on MRI images in discriminating glioblastoma from solitary brain metastases: a multicentre study," *BMC Medical Imaging*, vol. 25, no. 1, p. 171, 2025, doi: 10.1186/s12880-025-01703-3.
8. P. Familiari, A. Frati, A. Pesce, M. Miscusi, M. Cimatti, and A. Raco, "Real impact of intraoperative magnetic resonance imaging in newly diagnosed glioblastoma multiforme resection: an observational analytic cohort study from a single surgeon experience," *World Neurosurgery*, vol. 116, pp. e9–e17, 2018, doi: 10.1016/j.wneu.2017.12.176.
9. R. S. D'Amico, B. C. Kennedy, and J. N. Bruce, "Neurosurgical oncology: advances in operative technologies and adjuncts," *Journal of Neuro-Oncology*, vol. 119, no. 3, pp. 451–463, 2014, doi: 10.1007/s11060-014-1493-3.
10. I. Khan, M. Waqas, and M. S. Shamim, "Role of intra-operative MRI (iMRI) in improving extent of resection and survival in patients with glioblastoma multiforme," *JPMA: The Journal of the Pakistan Medical Association*, vol. 67, no. 7, pp. 1121–1123, 2017.
11. C. N. Kersch, P. Ambady, B. E. Hamilton, and R. F. Barajas Jr., "MRI and PET of brain tumor neuroinflammation in the era of immunotherapy," *American Journal of Roentgenology*, vol. 218, no. 4, pp. 582–596, 2022, doi: 10.2214/AJR.21.26159.
12. D. Schomas et al., "Glioblastoma imaging biomarkers for recurrence prediction: a prospective multicenter study," *Neuro-Oncology*, vol. 22, no. 5, pp. 675–684, 2020, doi: 10.1093/neuonc/noaa003.
13. T. Batchala et al., "Neuroimaging-based classification algorithm for predicting IDH-mutation status in glioblastoma," *American Journal of Neuroradiology*, vol. 40, no. 3, pp. 426–432, 2019, doi: 10.3174/ajnr.A5957.
14. M. López-González et al., "Diffusion tensor imaging and white matter tractography in glioblastoma: systematic review and meta-analysis of preoperative planning utility," *Journal of Neurosurgery*, vol. 136, no. 2, pp. 382–393, 2022, doi: 10.3171/2021.1.JNS203348.

15. B. Ellingson et al., "Consensus recommendations for standardized brain tumor imaging protocols in clinical trials," *Neuro-Oncology*, vol. 17, no. 9, pp. 1188–1198, 2015, doi: 10.1093/neuonc/nov095.