Journal of
Medical Research and Surgery

Research Article

Shayan A, et al. J Med Res Surg 2026, 7:1

Assessment of MRI Accuracy for Intra-Axial Glioma Diagnosis and Grading

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Received date: January 24, 2026; **Accepted date:** February 03, 2026; **Published date:** February 10, 2026

Citation: Shayan A, Shaikh A, Khattri Y, et al. Assessment of MRI Accuracy for Intra-Axial Glioma Diagnosis and Grading. *J Med Res Surg*. 2026;7(1):7-12. doi:10.52916/jmrs264196

ABSTRACT

Objective: To evaluate the diagnostic accuracy of MRI in detecting intra-axial gliomas and differentiating low- from high-grade tumors, using histopathology as the gold standard.

Methods: A cross-sectional study of 226 patients aged 15-60 years undergoing brain MRI was conducted at Liaquat National Hospital, Karachi. MRI findings were compared with histopathology. Sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and accuracy were calculated, with stratification by age, gender, residence, symptom duration, and clinical features.

Results: Mean age was 38.9 ± 9.8 years; 71.2% were male. MRI detected intra-axial gliomas in 58% of patients versus 60.6% confirmed by histopathology. For tumor detection, MRI sensitivity was 83.2%, specificity 80.9%, PPV 87%, NPV 75.8%, and accuracy 82.3%. For grading, MRI sensitivity was 90.1%, specificity 86%, PPV 91.4%, NPV 84.1%, and accuracy 88.6%. Accuracy was highest in females and patients over 35 years, and in those presenting with seizures or vomiting.

Conclusion: MRI provides high diagnostic accuracy for detection and grading of intra-axial gliomas. Multiparametric MRI protocols, incorporating diffusion and perfusion metrics, enhance non-invasive tumor characterization and support clinical decision-making.

Keywords:

Intra-axial glioma, MRI, Diagnostic accuracy, Glioma grading, Histopathology.

Introduction

Accurate and early diagnosis of intra-axial gliomas is essential for optimal clinical management, surgical planning, and prognostication. Gliomas are primary central nervous system tumors that arise from glial cells and represent one of the most common primary brain tumors in adults; they comprise about 30% of all brain and central nervous system tumors and roughly 80–85% of malignant primary brain tumors [1-3]. These tumors display varied biological behavior and clinical outcomes, and their prognosis depends predominantly on tumor grade, which is defined by histopathological and molecular features in contemporary classifications [4]. Patients with gliomas often present with nonspecific neurological symptoms that reflect both local tumor effects and raised intracranial pressure. The most common clinical features include headache, seizures, focal neurological deficits (such as motor weakness or sensory changes), and cognitive dysfunction [4,5].

Magnetic resonance imaging remains the gold standard for initial glioma assessment due to its superior soft-tissue contrast, multiplanar visualization, and lack of ionizing radiation [3,5]. Conventional sequences such as T1-weighted, T2-weighted, and FLAIR (especially with gadolinium enhancement) are routinely used to identify tumor location, extent, and morphologic features indicative of intra-axial glioma [6]. Advanced MRI techniques add functional and metabolic detail: Diffusion-Weighted Imaging (DWI) and ADC mapping provide information on cellularity; Perfusion-Weighted Imaging (PWI) Relative Cerebral Blood Volume (rCBV) assesses tumor vascularity; and MR Spectroscopy (MRS) evaluates metabolic profiles within lesions [7,8]. A recent study showed that combining mean ADC and rCBV significantly improves differentiation between high-grade and low-grade gliomas, achieving an AUC of 0.975 with 92.5% sensitivity and 91.3% specificity. These multiparametric approaches enhance noninvasive glioma grading and support treatment planning [9].

Existing literature shows that conventional MRI has high sensitivity and moderate specificity for detecting intra-axial gliomas when compared with histopathological outcomes, with overall diagnostic accuracy in many cohorts near the 87%-90% range. A cross-sectional study at the Dow Institute of Radiology reported that conventional MRI achieved a sensitivity of 89.3%, specificity of 73.9%, and overall diagnostic accuracy of 87.0% for detecting intra-axial gliomas, using histopathology as the reference standard [10]. Recent regional investigations similarly support MRI as the modality of choice in suspected glioma cases, demonstrating high diagnostic performance metrics in clinical practice [11]. In addition to detection, MRI features such as contrast enhancement patterns, necrosis, and peritumoral edema have shown promising correlations with histopathological glioma grades, although the accuracy of grading based solely on conventional imaging varies between studies and depends on imaging criteria and reader experience [12].

Advanced MRI methods further enhance non-invasive glioma characterization. Multiparametric MRI protocols that combine diffusion and perfusion metrics, including the apparent diffusion

coefficient from diffusion-weighted imaging and relative cerebral blood volume from perfusion-weighted imaging, have demonstrated strong performance in distinguishing high-grade gliomas from low-grade gliomas. In a recent clinical study, the combination of mean ADC and rCBV achieved an area under the curve of 0.975, with 92.5% sensitivity and 91.3% specificity for differentiating high-grade from low-grade gliomas, highlighting how integrated diffusion and perfusion metrics can closely approximate histopathologic grading accuracy [13]. Furthermore, broader multiparametric MRI assessments that include diffusion, perfusion, and spectroscopy show significant differences in functional parameters between glioma grades and correlate with histopathology, supporting their diagnostic utility in preoperative evaluation. In multiparametric models, perfusion parameters such as rCBV and diffusion parameters such as ADC are often significantly higher or lower, respectively, in high-grade tumors compared with low-grade tumors, reflecting increased vascularity and cellularity [14]. Systematic evaluations of perfusion MRI biomarkers also confirm their high diagnostic value for glioma grading, reinforcing multiparametric MRI as a valuable complement to conventional sequences [15].

Despite these improvements, data on MRI's diagnostic performance in many clinical settings, particularly in South Asia, remain limited and derived from relatively small samples. The present study aims to fill this gap by investigating the diagnostic accuracy of MRI in detecting intra-axial gliomas and in distinguishing low-grade from high-grade tumors, using histopathology as the gold standard.

Materials and Methods

This cross-sectional study was conducted in the Department of Radiology, Liaquat National Hospital and Medical College, Karachi, from 26 May to 25 November 2023. A total of 226 patients aged 15-60 years, of either gender, presenting with headache and/or fits for more than 15 days and undergoing brain MRI were enrolled using non-probability consecutive sampling. Exclusion criteria included pregnancy, incomplete MRI, inability to provide consent, allergy to contrast, or abnormal renal function. The sample size was calculated based on an expected MRI sensitivity of 86%, specificity of 76%, prevalence of intra-axial glioma of 51.5%, 95% confidence level, and 8% precision [16].

After ethical approval and written informed consent, baseline demographics and clinical features were recorded. All patients underwent MRI, and findings were assessed for presence and grade of intra-axial glioma. Patients undergoing biopsy or surgery within one month were followed, and histopathology was used as the gold standard for confirmation and grading. Data were recorded on a predesigned proforma, with strict adherence to inclusion and exclusion criteria to minimize bias.

Data analysis was performed using SPSSv25. Continuous variables were expressed as mean ± SD or median (IQR), and categorical variables as frequencies and percentages. Diagnostic performance of MRI for detection and grading of glioma was calculated using 2 × 2 contingency tables, and stratified analysis was performed by age, gender, residence, symptom duration, and clinical features. A p-value ≤ 0.05 was considered significant.

Results

A total of 226 patients aged 15 to 60 years were included in the study. The mean age was 38.89 ± 9.82 years. The majority were male (71.2%, n=161), and most patients resided in urban areas (67.3%, n=152). The most common presenting symptoms were seizures (69%, n=156), vomiting (60.2%, n=136), weakness (43.8%, n=99), headache (26.1%, n=59), and vertigo (21.7%, n=49). Co-morbidities were present in 16.4% of patients (n=37). Detailed patient demographics and clinical characteristics are summarized in Table 1.

Table 1: Patient demographics and clinical characteristics (n=226).

Variable	Frequency (%)
Gender	
Male	161 (71.2)
Female	65 (28.8)
Residence	
Urban	152 (67.3)
Rural	74 (32.7)
Symptoms	
Headache	59 (26.1)
Seizures	156 (69)
Vertigo	49 (21.7)
Vomiting	136 (60.2)
Weakness	99 (43.8)
Co-morbidities	37 (16.4)

Detection of Intra-Axial Glioma by MRI

In this study of 226 patients, MRI demonstrated good diagnostic performance for intra-axial gliomas, with overall sensitivity 83.2%, specificity 80.9%, PPV 87%, NPV 75.8%, and accuracy 82.3% (<p=0.001). Performance was slightly higher in females and in patients >35 years, while low specificity was observed in younger patients (≤ 35 years). Urban and rural populations showed comparable accuracy. MRI sensitivity and accuracy were higher in patients presenting with headache, weakness, or vertigo, and lower in those with vomiting or seizures. Patients without co-morbidities had slightly better results. For glioma grading, MRI reliably identified high-grade tumors with sensitivity 90.1%, specificity 86%, PPV 91.4%, NPV 84.1%, and accuracy 88.6%, whereas detection of low-grade gliomas was less consistent (Table 2).

MRI Detection of Glioma Grade

MRI showed high accuracy in grading intra-axial gliomas in 114 patients, with overall sensitivity 90.1%, specificity 86%, PPV 91.4%, NPV 84.1%, and accuracy 88.6% (<p=0.001). Females and patients over 35 years achieved perfect or near-perfect grading accuracy, while males and younger patients had slightly lower but still high performance. Urban and rural populations had comparable results. Shorter symptom duration, presence of headache, vertigo, vomiting, fits, or absence of co-morbidities generally improved grading accuracy. MRI demonstrated exceptional sensitivity and predictive values for patients presenting with vomiting (sensitivity 100%, accuracy 98.3%) (Table 3).

Table 2: Diagnostic accuracy of MRI for detection of intra-axial glioma.

Variable	MRI Positive/ Negative	Total	Sensitivity	Specificity	PPV	NPV	Accuracy	P-value*
Overall	114/23	226	83.2	80.9	87	75.8	82.3	0.000
Gender								
Male	78/17	95	82.1	80.3	85.7	75.7	81.36	0.000
Female	36/6	42	85.7	82.6	90	76	84.61	0.000
Age group								
≤ 35 yrs	74/22	96	77.1	0	91.4	0	71.84	0.153
>35 yrs	40/1	41	97.6	87.8	80	98.6	91.05	0.000
Residence								
Urban	77/14	91	84.6	77	84.6	77	81.57	0.000
Rural	37/9	46	80.4	89.3	92.5	73.5	83.78	0.000
Symptoms duration								
≤ 30 days	53/7	60	88.3	73.8	82.8	81.6	82.35	0.000
>30 days	61/16	77	79.2	87.2	91	71.9	82.25	0.000
Headache								
Yes	38/1	39	97.4	80	90.5	94.1	91.52	0.000
No	76/22	98	77.6	81.2	85.4	71.8	79.04	0.000
Fits								
Yes	70/22	92	76.1	79.7	84.3	69.9	77.56	0.000
No	44/1	45	97.8	84	91.7	95.5	92.85	0.000
Vertigo								
Yes	31/1	32	96.9	76.5	88.6	92.9	89.79	0.000
No	83/22	105	79	81.9	86.5	72.8	80.22	0.000
Vomiting								
Yes	59/19	78	75.6	77.6	81.9	70.3	76.47	0.000
No	55/4	59	93.2	87.1	93.2	87.1	91.11	0.000
Weakness								
Yes	62/4	66	93.9	87.9	93.9	87.9	91.91	0.000
No	52/19	71	73.2	76.8	80	69.4	74.80	0.000
Other co-morbids								
Yes	14/3	17	82.4	70	70	82.4	75.67	0.001
No	100/20	120	83.3	84.1	90.1	74.4	83.59	0.000
Glioma grade								
High	64/7	71	90.1	86	91.4	84.1	88.59	0.000
Low	6/37	43	–	–	–	–	–	–

Discussion

Intra-axial gliomas are among the most aggressive primary brain tumors, characterized by rapid progression, mass effect, elevated intracranial pressure, and significant neurological deterioration. Accurate and timely diagnosis is essential not only for initiating appropriate therapeutic interventions but also for predicting clinical outcomes. MRI remains the cornerstone of imaging evaluation due to its unparalleled soft-tissue contrast, multiplanar capabilities, and ability to non-invasively characterize tumor morphology and functional properties [17-20]. By combining conventional sequences with advanced imaging techniques, such as Diffusion-Weighted Imaging (DWI), Perfusion-Weighted Imaging (PWI), and spectroscopy, MRI enables detailed assessment of tumor cellularity, vascularity, necrosis, and hemodynamics, which often correlate strongly with histopathological and molecular features [19,20]. These capabilities support the modern WHO framework emphasizing integrated diagnoses that combine histology and molecular markers for precise tumor classification [17,18,20].

In our study, conventional MRI demonstrated a sensitivity of 83.2%, specificity of 80.9%, and overall diagnostic accuracy of 82.3% for identifying intra-axial gliomas, using histopathology

Table 3: Diagnostic accuracy of MRI for glioma grading.

Variable/Sub-group	MRI High/Low vs Histopathology	Total	Sensitivity	Specificity	PPV	NPV	Accuracy	P-value*
Overall	64/37	114	90.1	86%	91.4	84.1	88.59	0.000
Gender								
Male	47/28	78	87	87.5	94	75	87.17	0.000
Female	17/16	36	100	84.2	85	100	91.66	0.000
Age group								
≤ 35 yrs	42/26	74	85.7	76	87.5	73.1	82.43	0.000
>35 yrs	22/18	40	100	100	100	100	100	0.000
Residence								
Urban	45/29	77	90	88.9	93.8	82.8	89.61	0.000
Rural	19/15	37	90.5	81.3	86.4	86.7	86.48	0.000
Symptoms duration								
≤ 30 days	31/17	53	91.2	73.7	86.1	82.4	84.90	0.001
>30 days	33/27	61	89.2	95.8	97.1	85.2	91.80	0.000
Headache								
Yes	27/8	38	93.1	66.7	90	75	86.84	0.000
No	37/36	76	88.1	91.2	92.5	86.1	89.47	0.000
Fits								
Yes	36/33	70	92.3	96.8	97.3	90.9	94.28	0.000
No	28/11	44	87.5	58.3	84.8	63.6	79.54	0.004
Vertigo								
Yes	23/5	31	92	50	88.5	60	83.87	0.012
No	41/39	83	89.1	91.9	93.2	87.2	90.36	0.000
Vomiting								
Yes	34/24	59	100	96	97.1	100	98.30	0.000
No	30/20	55	81.1	72.2	85.7	65	78.18	0.000
Weakness								
Yes	35/22	62	83.3	75	87.5	68.2	80.64	0.000
No	29/22	52	100	95.7	96.7	100	98.07	0.000
Other co-morbids								
Yes	7/7	14	87.5	100	100	85.7	92.85	0.001
No	57/37	100	90.5	83.8	90.5	83.8	88	0.000

as the reference standard. These results align closely with global literature, which reports high sensitivity and moderate-to-high specificity for conventional MRI in glioma detection [10,11,21]. MRI excels in depicting critical features such as perilesional edema, necrosis, hemorrhage, mass effect, and contrast enhancement patterns, all of which contribute to accurate lesion detection and assist neurosurgeons in preoperative planning [12,22,23].

Tumor grading is a key determinant of management strategy and prognosis. Our study found MRI to differentiate high-grade from low-grade gliomas with a sensitivity of 90.1%, specificity of 86%, and overall accuracy of 88.6%. These findings are consistent with prior studies and meta-analyses indicating that both conventional and advanced MRI techniques achieve high diagnostic performance for glioma grading [13, 24-26]. High-grade gliomas typically exhibit heterogeneous enhancement, pronounced necrosis, elevated vascularity, and marked peritumoral edema features readily identified on MRI facilitating reliable preoperative stratification. Moreover, multiparametric approaches that combine DWI, PWI, and Relative Cerebral Blood Volume (rCBV) measurements have shown improved differentiation between tumor grades, with reported sensitivities and specificities exceeding 90% [13]. Such functional imaging metrics enhance the predictive value of MRI beyond morphology alone, enabling more confident clinical decision-making regarding surgical resection, radiotherapy, and adjuvant treatments.

Comparisons with local studies reinforce the robustness of our findings. Previous cohorts in Pakistan have reported diagnostic accuracy for intra-axial gliomas ranging from 81.5% to 91.5%,

with sensitivities consistently above 85% and specificities between 73% and 94% [10,11,27]. The slightly higher specificity in our study may reflect assessment of tumor architecture, optimized imaging protocols, and growing expertise among radiologists. Subgroup analyses highlighted that MRI accuracy was particularly high in patients presenting with headache, seizures, motor weakness, or vomiting, suggesting that careful integration of clinical presentation with imaging features enhances diagnostic yield. Diagnostic performance was also superior in patients >35 years and those with prolonged symptom duration, likely reflecting more pronounced radiological findings in advanced disease.

MRI offers distinct advantages compared with other imaging modalities. Its superior soft-tissue contrast and multiplanar acquisition facilitate precise anatomical localization and delineation of tumor margins. Functional sequences provide critical insights into tumor biology, including vascularity and cellular density, without exposure to ionizing radiation [19]. These characteristics make MRI the ideal modality for longitudinal follow-up, preoperative planning, and assessment of treatment response. Importantly, MRI is also instrumental in distinguishing tumor recurrence from post-treatment changes, such as radiation-induced necrosis, which is critical for guiding subsequent therapeutic decisions [13,24-26].

Conclusion

MRI is a reliable and non-invasive modality for detecting and grading intra-axial gliomas, showing high sensitivity, specificity, and diagnostic accuracy compared to histopathology. Its superior soft-tissue contrast and multiplanar imaging allow accurate tumor characterization, aiding preoperative planning and treatment decisions. These findings support MRI as the primary imaging tool for suspected gliomas, with potential for further improvement using standardized protocols and advanced imaging techniques.

Conflict of Interest

The authors declared no conflict of interest.

Funding

None.

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