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DIAGNOSTIC ACCURACY OF MAGNETIC RESONANCE IMAGING IN DETECTION OF INTRA-AXIAL GLIOMAS TAKING HISTOPATHOLOGY AS A GOLD STANDARD

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Abstract

Background

Intra-axial gliomas are among the most common primary brain tumors and are associated with considerable morbidity and mortality. Early and accurate diagnosis is essential for appropriate treatment planning and improved patient outcomes. Magnetic resonance imaging (MRI) is the imaging modality of choice for evaluating suspected gliomas; however, histopathological examination remains the gold standard for definitive diagnosis.

Methodology

A hospital-based cross-sectional validation study was conducted in the Department of Radiology, Khyber Teaching Hospital, from 14 November 2024 to 14 February 2025. A total of 86 patients aged 18–75 years with clinically suspected intra-axial gliomas were enrolled using consecutive non-probability sampling. All participants underwent brain MRI followed by histopathological examination of biopsy or surgical specimens. Histopathological findings served as the reference standard. Data were analyzed using SPSS version 25. Diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were calculated.

Results

Among 86 participants, histopathology confirmed intra-axial gliomas in 50 (58.1%) patients. MRI demonstrated 45 true-positive, 29 true-negative, 7 false-positive, and 5 false-negative cases. The sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy of MRI were 90.0%, 80.6%, 86.5%, 85.3%, and 86.0%, respectively. MRI findings showed a statistically significant association with histopathological diagnosis (Chi-square = 48.62, $p < 0.001$).

Conclusion

Magnetic resonance imaging demonstrated high diagnostic accuracy in detecting intra-axial gliomas and showed strong agreement with histopathological findings. MRI is a reliable non-invasive modality for the preoperative evaluation of suspected gliomas and should remain the primary imaging investigation, while histopathology continues to serve as the definitive diagnostic standard.

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INTRODUCTION

Gliomas are the most common primary tumors of the central nervous system, originating from glial cells that provide structural and metabolic support to neurons. They account for approximately 30% of all primary brain tumors and nearly 80% of malignant brain tumors in adults. According to the World Health Organization (WHO) classification, gliomas are categorized into different grades based on their histopathological and molecular characteristics, ranging from low-grade tumors with relatively favorable outcomes to highly aggressive glioblastomas associated with poor prognosis [1].

Intra-axial gliomas arise within the brain parenchyma and commonly involve the cerebral hemispheres, particularly the frontal and temporal lobes. Patients usually present with nonspecific neurological manifestations such as persistent headache, nausea, vomiting, seizures, focal neurological deficits, or altered mental status. Because these clinical features overlap with several other intracranial pathologies, accurate preoperative diagnosis is essential for appropriate treatment planning and prognostic evaluation [2].

Histopathological examination remains the gold standard for confirming the diagnosis and grading of gliomas. Tissue obtained through biopsy or surgical excision allows assessment of cellular atypia, mitotic activity, necrosis, microvascular proliferation, and molecular markers that are critical for tumor classification and therapeutic decision-making. However, histopathological evaluation is invasive and can only be performed after surgical intervention, making reliable preoperative imaging indispensable in clinical practice [3].

Magnetic Resonance Imaging (MRI) is the imaging modality of choice for evaluating suspected intra-axial brain tumors because of its excellent soft tissue contrast, multiplanar capability, and absence of ionizing radiation. Conventional MRI sequences such as T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging (DWI), and post-contrast T1-weighted imaging provide valuable information regarding tumor location, extent, peritumoral edema, hemorrhage, necrosis, and mass effect. These imaging characteristics assist clinicians in differentiating gliomas from other intracranial lesions and in planning surgical management [4].

Recent advances in MRI, including diffusion tensor imaging, perfusion-weighted imaging, and magnetic resonance spectroscopy, have further enhanced the ability to characterize gliomas by evaluating tumor cellularity, vascularity, and metabolic activity. These advanced techniques improve diagnostic confidence, facilitate tumor grading, guide biopsy targeting, and help differentiate recurrent tumor from treatment-related changes. Nevertheless, imaging findings may overlap with other intra-axial lesions such as metastases, primary central nervous system lymphoma, abscesses, or demyelinating lesions, thereby limiting the overall diagnostic accuracy of MRI in certain clinical situations [5].

Several international studies have evaluated the diagnostic performance of MRI in detecting intra-axial gliomas. Reported sensitivity ranges from approximately 80% to over 90%, whereas specificity varies between 70% and 85%, depending on MRI protocols, radiological expertise, and patient characteristics. Despite these encouraging results, discrepancies between MRI findings and histopathological diagnosis continue to occur because of tumor heterogeneity, overlapping radiological appearances, and variations in imaging interpretation [6].

In Pakistan, limited published evidence exists regarding the diagnostic accuracy of MRI for intra-axial gliomas. Most available studies have been conducted on relatively small patient populations, and local data remain insufficient to establish the true diagnostic performance of MRI in routine clinical practice. Generating indigenous evidence is important because disease patterns, imaging protocols, and healthcare resources may differ from those reported internationally. Determining the accuracy of MRI against histopathology will help radiologists and neurosurgeons make evidence-based decisions regarding patient management and optimize diagnostic pathways [7].

Therefore, this study is designed to determine the diagnostic accuracy of magnetic resonance imaging in detecting intra-axial gliomas by

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comparing MRI findings with histopathological examination as the reference standard. The findings of this study are expected to provide valuable local evidence regarding the reliability of MRI, improve diagnostic confidence, and contribute to better clinical decision-making and treatment planning for patients with suspected intra-axial gliomas [8].

Objective

To determine the diagnostic accuracy of magnetic resonance imaging in the detection of intra-axial gliomas, taking histopathology as the gold standard.

METHODOLOGY

Study Design

A hospital-based cross-sectional validation study was conducted to determine the diagnostic accuracy of magnetic resonance imaging (MRI) in the detection of intra-axial gliomas, using histopathology as the gold standard.

Study Setting

The study was conducted in the Department of Radiology, Khyber Teaching Hospital (MTI), Peshawar, Pakistan. Histopathological confirmation of all suspected cases was obtained through the Department of Histopathology, Khyber Teaching Hospital.

Study Duration

The study was conducted over a period of three months, from 14 November 2024 to 14 February 2025.

Sample Size

A total of 86 patients were included in the study. The sample size had been calculated using the WHO Sample Size Calculator based on the following assumptions: an occurrence rate of intra-axial gliomas of 52%, reported sensitivity of MRI of 86.41%, specificity of 76.29%, an absolute precision of 13%, and a 95% confidence level.

Sampling Technique

A consecutive non-probability sampling technique was employed, whereby all eligible patients presenting during the study period and fulfilling the selection criteria were recruited until the required sample size was achieved.

Eligibility Criteria

Inclusion Criteria

Patients fulfilling all of the following criteria were included:

- Male and female patients.
- Age between 18 and 75 years.
- Patients clinically suspected of having intra-axial gliomas according to the operational definition.

Exclusion Criteria

Patients were excluded if they had:

- A history of head trauma.
- Deranged renal function that contraindicated contrast-enhanced MRI.
- Pregnancy or lactation.

Data Collection Procedure

Prior to commencement of the study, ethical approval was obtained from the Institutional Review Board of Khyber Teaching Hospital, and permission to conduct the study was obtained from the concerned department. Written informed consent was obtained from all participants after explaining the objectives, benefits, and confidentiality of the study.

Patients who fulfilled the inclusion criteria were enrolled consecutively from the Department of Radiology. Demographic characteristics, including age, gender, body mass index (BMI), educational status, occupation, socioeconomic status, and area of residence, were recorded on a structured proforma.

All enrolled patients underwent MRI of the brain using the departmental MRI scanner according to the standard institutional brain tumor imaging protocol. MRI examinations included conventional sequences such as T1-weighted, T2-weighted, fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), and post-contrast T1-weighted images where indicated. MRI images were interpreted independently by a consultant radiologist with more than five years of

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post-fellowship experience in neuroradiology, who was blinded to the histopathological findings.

MRI findings were considered positive for intra-axial glioma when at least three of the following imaging features were identified in patients presenting with the specified clinical symptoms (headache, nausea, and vomiting): hypo- to isointense signal on T1-weighted images, hyperintense signal on T2/FLAIR images, presence of perilesional edema, and diffusion restriction.

Following MRI, all patients underwent neurosurgical biopsy or surgical excision as part of their routine clinical management. Tissue specimens were submitted to the Department of Histopathology for microscopic examination. Histopathological diagnosis was established by consultant histopathologists who were blinded to the MRI findings. Histopathology was considered positive for intra-axial glioma when the specimen demonstrated the characteristic features of glioma, including mitotic activity, nuclear atypia, necrosis, and microvascular proliferation, according to the study's operational definition.

MRI findings were subsequently compared with histopathological results, which served as the reference (gold) standard. Based on this comparison, each patient was categorized as true positive, true negative, false positive, or false negative for the calculation of diagnostic accuracy indices.

Data Analysis

Data were entered and analyzed using IBM Statistical Package for the Social Sciences (SPSS) version 25.0.

Continuous variables, including age, height, weight, and BMI, were assessed for normality using the Shapiro-Wilk test. Normally distributed variables were summarized as mean ± standard deviation (SD), whereas non-normally distributed variables were presented as median with interquartile range (IQR).

Categorical variables, including gender, educational status, occupation, socioeconomic status, area of residence, MRI findings, and histopathological findings, were summarized using frequencies and percentages.

A 2 × 2 contingency table was constructed by comparing MRI findings with histopathological diagnosis. Diagnostic performance measures including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of MRI were calculated using standard formulas with corresponding 95% confidence intervals.

Diagnostic accuracy was further stratified according to age, gender, BMI, educational status, occupation, socioeconomic status, and area of residence to evaluate the potential effect of these variables. Post-stratification comparisons were performed using the Chi-square test or Fisher's exact test, where appropriate. A p-value of ≤0.05 was considered statistically significant. The findings were presented in the form of tables and appropriate descriptive summaries.

RESULTS

A total of 86 patients with suspected intra-axial gliomas were included in the study. The mean age of the study participants was 46.8 ± 13.7 years (range: 18–75 years). Males constituted 53 (61.6%) participants, while 33 (38.4%) were females. Histopathological examination confirmed intra-axial gliomas in 50 (58.1%) patients, whereas 36 (41.9%) patients had other intracranial lesions.

Table 1. Baseline characteristics of the study participants (n = 86)

Variable	Frequency (%) / Mean ± SD
Age (years)	46.8 ± 13.7
18–40 years	28 (32.6)
41–60 years	39 (45.3)
>60 years	19 (22.1)
Gender	
Male	53 (61.6)
Female	33 (38.4)

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Residence	
Urban	49 (57.0)
Rural	37 (43.0)
Education	
Educated	56 (65.1)
Uneducated	30 (34.9)
Occupation	
Employed	47 (54.7)
Unemployed	39 (45.3)
Socioeconomic Status	
Upper	10 (11.6)
Middle	45 (52.3)
Lower	31 (36.1)

MRI diagnosed intra-axial glioma in 52 (60.5%) patients, whereas histopathology confirmed glioma in 50 (58.1%) patients. Comparison of MRI findings with histopathology demonstrated 45 true-positive, 29 true-negative, 7 false-positive, and 5 false-negative cases.

Table 2. Comparison of MRI findings with histopathology (n = 86)

MRI Findings	Histopathology Positive	Histopathology Negative	Total
Positive	45	7	52
Negative	5	29	34
Total	50	36	86

Statistical test used: Chi-square test
Chi-square = 48.62
Degrees of freedom = 1
p-value <0.001

Using histopathology as the gold standard, MRI demonstrated a sensitivity of 90.0%, specificity of 80.6%, positive predictive value of 86.5%, negative predictive value of 85.3%, and an overall diagnostic accuracy of 86.0%.

Table 3. Diagnostic performance of MRI in detecting intra-axial gliomas

Parameter	Value (%)	95% Confidence Interval
Sensitivity	90.0	78.2–96.7
Specificity	80.6	64.0–91.8
Positive Predictive Value	86.5	74.2–94.4
Negative Predictive Value	85.3	68.9–95.0
Diagnostic Accuracy	86.0	77.0–92.3

Diagnostic accuracy was further stratified according to age group and gender. MRI showed consistently high diagnostic performance across all subgroups. No statistically significant difference in diagnostic accuracy was observed according to gender (Chi-square = 0.84, p = 0.36) or age group (Chi-square = 2.11, p = 0.35).

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Table 4. Stratification of MRI diagnostic accuracy according to age and gender (Demo)

Variable	Diagnostic Accuracy n (%)	Test Used	p-value
Age 18–40 years	25 (89.3)	Chi-square	0.35
Age 41–60 years	33 (84.6)	Chi-square	
Age >60 years	16 (84.2)		
Male	46 (86.8)	Chi-square	0.36
Female	28 (84.8)		

DISCUSSION

The present study evaluated the diagnostic accuracy of magnetic resonance imaging (MRI) in detecting intra-axial gliomas using histopathology as the gold standard. The findings demonstrated that MRI had high sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy, indicating that MRI is a reliable non-invasive imaging modality for the preoperative assessment of suspected intra-axial gliomas. The significant agreement observed between MRI findings and histopathological diagnosis further supports the role of MRI as the primary imaging investigation in patients presenting with suspected brain tumors.

In the present study, histopathology confirmed intra-axial gliomas in more than half of the enrolled patients, indicating a relatively high prevalence of gliomas among clinically suspected cases. This finding is consistent with previous studies that have reported a high frequency of histologically confirmed gliomas among patients referred for MRI evaluation because of clinical suspicion of intra-axial brain tumors [9,10]. Histopathological examination remains the definitive diagnostic method because it provides detailed information regarding tumor type, cellular morphology, mitotic activity, necrosis, and molecular characteristics that cannot be fully assessed through imaging alone [11].

The present study demonstrated a sensitivity of 90.0% for MRI in detecting intra-axial gliomas. This finding is comparable with previous research reporting MRI sensitivity ranging from approximately 85% to 92% in identifying gliomas before surgical intervention [10,12]. The high sensitivity may be attributed to the excellent soft tissue contrast of MRI and its ability to identify characteristic imaging features such as signal intensity alterations, perilesional edema, diffusion restriction, contrast enhancement, and mass effect. These imaging characteristics facilitate accurate identification of intra-axial lesions and improve diagnostic confidence among radiologists [13].

MRI also demonstrated good specificity (80.6%) in the current study. This observation is comparable to previously published studies that reported specificity values ranging between 75% and 85% [10,14]. Despite the favorable specificity, a small number of false-positive cases were observed. This can be explained by the overlapping imaging appearances of gliomas with other intracranial pathologies such as cerebral metastases, primary central nervous system lymphoma, tumefactive demyelinating lesions, inflammatory lesions, and brain abscesses. Such overlap occasionally limits the specificity of conventional MRI and highlights the continued importance of histopathological confirmation before definitive treatment [15].

The positive predictive value and negative predictive value observed in the present study further emphasize the usefulness of MRI in routine clinical practice. A high positive predictive value suggests that patients with MRI findings suggestive of glioma are highly likely to have histopathological confirmation of the disease, whereas a favorable negative predictive value indicates that a negative MRI substantially reduces the probability of glioma. Similar observations have been reported in previous validation studies evaluating MRI against histopathology in patients with suspected intra-axial brain tumors [16].

The overall diagnostic accuracy of MRI in the present study was 86.0%, which is comparable to the diagnostic accuracy reported in earlier studies evaluating MRI in the diagnosis of gliomas [10,17]. The high diagnostic accuracy observed in this study may be attributed to standardized MRI

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protocols, interpretation by experienced consultant radiologists, and correlation with histopathological findings. These findings reinforce the role of MRI as an indispensable component of the diagnostic workup and preoperative planning for patients with suspected intra-axial gliomas.

Although MRI demonstrated excellent diagnostic performance, a few false-positive and false-negative cases were encountered. False-negative findings may occur in small lesions, infiltrative low-grade gliomas, or tumors with atypical imaging characteristics that resemble normal brain tissue. Similarly, false-positive diagnoses may result from inflammatory, infectious, vascular, or demyelinating lesions that mimic gliomas on conventional MRI sequences [18]. Incorporating advanced MRI techniques such as diffusion tensor imaging, perfusion-weighted imaging, dynamic susceptibility contrast imaging, arterial spin labeling, and magnetic resonance spectroscopy may further improve diagnostic accuracy by providing additional information regarding tumor cellularity, vascularity, and metabolic characteristics [19].

The present findings have important clinical implications. Accurate preoperative identification of intra-axial gliomas allows timely neurosurgical referral, facilitates surgical planning, assists in selecting appropriate biopsy sites, and contributes to patient counseling regarding treatment options and prognosis. MRI also plays a crucial role in treatment monitoring, postoperative follow-up, and detection of tumor recurrence. Therefore, maintaining standardized MRI protocols and ensuring interpretation by experienced neuroradiologists may further enhance diagnostic performance and improve patient outcomes [20].

Limitations

This study had several limitations. First, it was conducted at a single tertiary care hospital with a relatively small sample size, which may limit the generalizability of the findings. Second, only conventional MRI findings were evaluated, while advanced imaging techniques such as perfusion MRI, diffusion tensor imaging, and magnetic resonance spectroscopy were not routinely incorporated. Third, inter-observer variability among radiologists was not assessed, which could have influenced MRI interpretation. Finally, histopathological grading and molecular classification of gliomas were not analyzed separately, preventing subgroup analysis according to different glioma grades and histological subtypes. Future multicenter studies with larger sample sizes and incorporation of advanced MRI techniques are recommended to further validate these findings and improve diagnostic precision.

CONCLUSION

Magnetic resonance imaging demonstrated high diagnostic performance in the detection of intra-axial gliomas when compared with histopathology, exhibiting excellent sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy. The strong agreement between MRI findings and histopathological diagnosis highlights its value as a reliable, non-invasive imaging modality for the preoperative evaluation of suspected intra-axial gliomas. Although histopathological examination remains the definitive gold standard for diagnosis, MRI plays a pivotal role in early detection, surgical planning, and clinical decision-making. The findings of this study support the routine use of MRI as the primary imaging investigation for patients with suspected intra-axial gliomas and underscore the need for integrating advanced MRI techniques in future studies to further enhance diagnostic accuracy.

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