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Comparative Analysis of MRI and CT Scan for the Diagnosis of Brain Tumor, Considering MRI as Gold Standard

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ABSTRACT

Background: Brain tumors pose a significant diagnostic challenge due to their diverse presentation and potential severity. While both MRI and CT scans are routinely employed in clinical settings, MRI is widely regarded as the gold standard for brain tumor evaluation due to its superior soft tissue resolution. However, real-world comparative data on their diagnostic accuracy, especially in resource-constrained settings, remain limited. **Objective:** This study aimed to compare the diagnostic accuracy, sensitivity, and specificity of MRI versus CT scan for the detection of brain tumors, considering MRI as the gold standard, and to evaluate their clinical utility in identifying specific brain lesion locations. **Methods:** This cross-sectional observational study enrolled 20 patients (n = 20) with suspected brain tumors at the National Hospital, Faisalabad, from February to May. Inclusion criteria included adults of either gender undergoing both CT and MRI; patients with contraindications to MRI or contrast allergy were excluded. CT scans were performed using a Toshiba Aquilion 64-slice scanner, and MRIs were conducted with a Toshiba Canon Titan 1.5T system. Data were collected using a standardized performa and analyzed using SPSS v26. Diagnostic performance was evaluated using cross-tabulations and Chi-square testing. Ethical standards were maintained per the Declaration of Helsinki with informed consent obtained from all participants. **Results:** MRI detected brain tumors in 60% of cases compared to 50% by CT. MRI identified more paraventricular lesions (62.5% vs. 17.6%) and frontal-occipital-temporal abnormalities (60.0% vs. 50.0%). Sensitivity and specificity of MRI were 100.0% and 80.0%, respectively. Chi-square testing confirmed statistical significance ($\chi^2 = 13.333$, $p < 0.001$), establishing MRI's clinical superiority for brain tumor diagnosis. **Conclusion:** MRI demonstrated higher diagnostic accuracy, particularly for lesion localization and parenchymal assessment, reinforcing its gold-standard status in brain tumor imaging. These findings support its prioritization in clinical protocols, improving early diagnosis and treatment planning in neuro-oncology. **Keywords:** Brain Neoplasms, Magnetic Resonance Imaging, Computed Tomography, Diagnostic Accuracy, Neuroimaging, Sensitivity and Specificity, Cross-Sectional Studies

INTRODUCTION

Brain tumors, characterized by abnormal cell growth within or surrounding the brain, represent one of the most intricate challenges in clinical neuroscience due to their diverse etiology, presentation, and prognosis. The spectrum of brain tumors ranges from benign and slow-growing lesions to aggressive and malignant neoplasms such as glioblastoma multiforme, which is associated with a median overall survival of merely fifteen months despite advancements in therapeutic interventions (4). Given the central role of accurate diagnosis in tailoring effective management strategies, imaging techniques such as

Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) have become indispensable tools in clinical practice (1). CT scanning, owing to its widespread availability and rapid acquisition time, is often employed as an initial imaging modality in emergency settings and for detecting intracranial hemorrhages or skull fractures. However, it is limited in its ability to differentiate soft tissues, which is a critical requirement in tumor evaluation (17). In contrast, MRI offers superior contrast resolution and multi-planar capabilities, enabling precise delineation of tumor boundaries, peritumoral

edema, mass effect, and infiltration into surrounding tissues (1). These qualities position MRI as the gold standard for brain tumor imaging.

Despite its widespread clinical application, the comparative diagnostic efficacy of CT and MRI remains a critical subject of investigation, particularly in resource-limited settings where access to MRI may be constrained. This study addresses a fundamental gap in the literature by providing a direct, case-based comparison between MRI and CT scan findings in the same cohort of patients with suspected brain tumors. Although prior research has consistently demonstrated MRI's superiority over CT in detecting small lesions, characterizing tumor heterogeneity, and minimizing artifacts from bone or air-filled structures (4, 16), real-world comparisons involving side-by-side evaluation of both modalities in the same clinical setting remain sparse. A landmark study by Schellinger *et al.* revealed that MRI detected multiple metastases missed by CT in 31% of cases (4), and Hesselink *et al.* reported a 98% detection rate of brain contusions by MRI, compared to just 56% with CT (16). These findings underscore the diagnostic limitations of CT and emphasize the critical need for comparative analysis in specific clinical populations to validate MRI's performance and justify its broader clinical adoption.

Furthermore, recent advancements in neuroimaging such as functional MRI (fMRI), diffusion tensor imaging (DTI), and MR spectroscopy have broadened the diagnostic landscape, yet these technologies remain largely inaccessible in many tertiary care facilities due to financial or infrastructural constraints (22). As such, evaluating the diagnostic yield of conventional MRI protocols against CT scans offers a pragmatic approach to understanding imaging trade-offs in standard hospital settings. The current study aims to contextualize this issue by analyzing imaging results from twenty patients subjected to both CT and MRI at a single clinical site. This dual-modality imaging approach, combined with a statistical analysis of sensitivity and specificity, provides robust data to inform clinical guidelines, particularly in healthcare environments where imaging modality selection must be judicious and evidence-based.

By leveraging insights from previously published works that utilized advanced machine learning techniques for brain tumor segmentation (2, 14), as well as studies exploring textural and morphological analysis of imaging data (13), this research builds a strong methodological foundation. The integration of image-based neural networks for tumor segmentation within the study's MRI evaluations adds an additional layer of relevance in light of the current push toward AI-assisted diagnostics (3, 9). While MRI's technical superiority is well-documented, real-world data examining its practical advantages over CT in routine diagnostic workflows, particularly in differentiating lesion types and brain regions affected, remain limited. Hence, this study not only reinforces MRI's diagnostic value but also evaluates its feasibility as a first-line modality in environments with limited access to advanced neuroimaging.

Given the above considerations, the present study is both timely and necessary. It investigates the diagnostic accuracy, sensitivity, and specificity of MRI compared to CT scans in

identifying brain tumors and associated abnormalities. The results aim to support radiological decision-making and patient management by presenting empirical evidence derived from a controlled, comparative clinical analysis. Based on the literature and observed clinical patterns, the central research hypothesis posits that MRI exhibits significantly higher sensitivity and diagnostic accuracy than CT scan in the evaluation of brain tumors. This hypothesis is explored through cross-sectional analysis and validated using statistical measures, including Chi-square tests, thereby contributing valuable insights to the evolving field of neuro-oncology imaging.

MATERIAL AND METHODS

The present study was a cross-sectional observational diagnostic accuracy study conducted over a four-month period, from February to May, at the Radiology Department of the National Hospital, Faisalabad. The study aimed to compare the diagnostic performance of computed tomography (CT) scans and magnetic resonance imaging (MRI) in detecting brain tumors, with MRI considered the gold standard. A total of 20 patients clinically suspected of having brain tumors were recruited through convenient, non-probability sampling. Inclusion criteria consisted of adult patients of either gender who presented with neurological symptoms warranting radiological evaluation and were eligible for both CT and MRI imaging. Exclusion criteria included patients with contraindications to MRI (e.g., metallic implants or pacemakers), those who declined imaging or participation, and those with known hypersensitivity to contrast agents, in which case only non-contrast scans were performed. Informed consent was obtained from all participants prior to data collection, and confidentiality of patient information was maintained in accordance with ethical principles outlined in the Declaration of Helsinki.

All participants underwent both CT and MRI scans as part of their diagnostic evaluation. CT scans were performed using a Toshiba Aquilion 64-slice scanner. Patients were positioned supine with arms at their sides, and all metallic objects were removed prior to scanning. Imaging parameters included a tube voltage of 120 kVp, slice thickness of less than 1 mm, and slice increment of 0.5 mm. Axial images were acquired from the base of the skull to the vertex, with a subset of patients undergoing contrast-enhanced scans depending on their clinical history and allergy status. MRI examinations were conducted using a Toshiba Canon Titan 1.5T scanner. MRI protocols involved T1- and T2-weighted sequences, including Fluid-Attenuated Inversion Recovery (FLAIR) images. Patients were scanned in the supine position with the head secured in a head coil, and instructed to remain still throughout the procedure. For T2-weighted sequences, repetition time (TR) ranged from 4100 to 5400 ms and echo time (TE) from 100 to 120 ms. Slice thickness was 3 mm, flip angle ranged from 132° to 151°, and matrix size was 320x320. For T2 FLAIR imaging, TR ranged from 6900 to 9100 ms, with similar imaging parameters.

The primary outcome of the study was the presence or absence of brain tumors or associated abnormalities, including

hyperdense areas, lesions in specific brain regions (frontal, occipital, temporal), midline shifts, and cerebral autopsies. These findings were recorded for both CT and MRI scans. Secondary outcomes included the sensitivity and specificity of MRI compared to CT scan. Data were collected using a standardized performa authorized by the Head of Department and Medical Superintendent, ensuring consistency in image interpretation. Image analysis was supported by convolutional neural network-based segmentation in MRI evaluations, aiding in lesion detection and categorization.

Statistical analysis was performed using IBM SPSS version 26. Descriptive statistics were used to summarize patient demographics, including mean age, gender distribution, and basic anthropometric data. Categorical variables, such as the presence of specific lesions or abnormalities, were expressed as frequencies and percentages. Continuous variables were

presented as means with standard deviations. Diagnostic accuracy metrics—sensitivity and specificity of MRI—were computed using 2x2 contingency tables with CT scan as the comparator. Chi-square tests were conducted to determine the statistical significance of differences in lesion detection between the two modalities. P-values less than 0.05 were considered statistically significant. Missing data were not imputed, and no adjustment for confounding variables was necessary due to the descriptive nature of the study (19).

RESULTS

A total of 20 patients clinically suspected of having brain tumors were enrolled in the study. The mean age of the participants was 46.15 ± 16.49 years, with a minimum age of 9 years and a maximum of 75 years. Males comprised 60% of the sample, and females constituted 40%.

Table 1. Descriptive Statistics for Patient Age

Statistic	Value
Mean age (years)	46.15
Standard deviation	16.49
Standard error	3.69
Median	46.5
Mode	62
Minimum	9
Maximum	75
Range	66
Sample variance	271.92

Table 2. CT Scan Findings in the Paraventricular Region

Finding	Frequency (n)	Percent (%)
Hyperdense area	10	58.8
Lacunar infarct	4	23.5
Lesions	3	17.6

Table 3. CT Scan Findings in Frontal, Occipital, and Temporal Regions

Finding	Frequency (n)	Percent (%)
Present	10	50.0
Absent	10	50.0

Table 4. Additional CT Scan Findings

Region/Feature	Frequency (n)	Percent of Cases (%)
Midline shift	15	75.0
Lesions in midbrain/pons/medulla	1	5.0
Cerebral autopsy	6	30.0
Calvarium intact	3	15.0

In CT imaging, hyperdense areas in the paraventricular region were detected in 58.8% of patients, lacunar infarcts in 23.5%, and paraventricular lesions in 17.6%. Midline shift was observed in 75.0% of patients. Lesions in the frontal, occipital, and temporal regions were detected in 50.0% of cases, while midbrain/pons/medulla lesions appeared in 5.0%. Cerebral autopsy changes were present in 30.0%, and the calvarium was intact in 15.0%. MRI results demonstrated hyperdense areas in the paraventricular region in 36.4% of responses (50.0% of patients), lacunar infarcts in 18.2% (25.0%), and paraventricular

lesions in 45.5% (62.5%). Like CT, MRI identified midline shifts in 75.0% of patients. Lesions in frontal, occipital, and temporal lobes were more frequently detected via MRI (60.0% vs. 50.0% on CT), and midbrain/pons/medulla involvement remained consistent at 4.3%. Cerebral autopsy findings were more frequent on MRI (34.8% vs. 30.0%), whereas calvarial integrity was slightly less frequently preserved (8.7% on MRI vs. 15.0% on CT). A comparative analysis between MRI and CT scan revealed that MRI detected 2 additional cases of brain tumors not identified by CT, highlighting MRI's higher sensitivity. The

diagnostic sensitivity of MRI was calculated at 100%, and specificity at 80% when using CT findings as the comparator. Chi-square testing revealed a statistically significant association between MRI and CT results in brain tumor

diagnosis ($\chi^2 = 13.33$, $df = 1$, $p < 0.001$), confirming the superiority of MRI in diagnostic yield. Fisher's Exact Test also yielded a significance level of $p = 0.001$, supporting these findings.

Table 5. MRI Findings in the Paraventricular Region

Finding	Frequency (n)	Percent of Responses (%)	Percent of Cases (%)
Hyperdense area	8	36.4	50.0
Lacunar infarct	4	18.2	25.0
Lesions	10	45.5	62.5

Table 6. MRI Findings in Frontal, Occipital, and Temporal Regions

Finding	Frequency (n)	Percent (%)
Present	12	60.0
Absent	8	40.0

Table 7. Additional MRI Findings

Region/Feature	Frequency (n)	Percent of Cases (%)
Midline shift	15	75.0
Lesions in midbrain/pons/medulla	1	6.3
Cerebral autopsy	8	50.0
Calvarium intact	2	12.5

Table 8. Contingency Table: MRI vs. CT for Brain Tumor Detection

	CT: Tumor Present	CT: Tumor Absent	Total
MRI: Tumor Present	10	2	12
MRI: Tumor Absent	0	8	8
Total	10	10	20

Table 9. Sensitivity and Specificity of MRI Relative to CT

Metric	Value (%)
Sensitivity	100.0
Specificity	80.0
Accuracy	90.0

Table 10. Chi-Square Test Results Comparing MRI and CT

Test	Value	df	p-value
Pearson Chi-Square	13.333	1	<0.001
Continuity Correction	10.208	1	0.001
Likelihood Ratio	16.912	1	<0.001
Fisher's Exact Test (2-sided)	—	—	0.001

MRI demonstrated superior diagnostic performance compared to CT, particularly in identifying lesions in the paraventricular, frontal, occipital, and temporal regions. While CT was equally effective in detecting midline shifts, MRI showed a higher diagnostic yield in cerebral autopsy and lesion localization. The high sensitivity (100%) and robust specificity (80%) affirm MRI's reliability as the gold standard in neuroimaging.

Although statistical significance was confirmed via Chi-square and Fisher's tests, clinical significance is also evident given MRI's ability to identify abnormalities in patients missed by CT—reinforcing its critical role in accurate brain tumor diagnosis. No post hoc adjustments were necessary due to the binary diagnostic nature of the data.

DISCUSSION

The present study provides a valuable contribution to the ongoing discourse on the comparative diagnostic accuracy of magnetic resonance imaging (MRI) and computed tomography (CT) in the evaluation of brain tumors. The findings affirm MRI's superior sensitivity and specificity, reinforcing its established role as the gold standard in neuroimaging for intracranial neoplasms. In our cohort of twenty clinically suspected cases, MRI demonstrated 100% sensitivity and 80% specificity when compared to CT scan, identifying two additional cases of brain tumors that were undetected by CT. These results are not only statistically significant but also clinically meaningful, as timely and accurate detection is essential in influencing therapeutic decision-making and prognosis in patients with brain tumors.

Our results are consistent with earlier studies that have explored the diagnostic value of MRI. Schellinger et al. (1999) found that MRI detected additional metastatic lesions in approximately one-third of patients previously diagnosed with solitary brain metastases via contrast-enhanced CT, highlighting MRI's superior lesion resolution and multiplanar imaging capability (4). Similarly, Bahadure et al. (2017) demonstrated that MRI, when integrated with machine learning techniques such as biologically inspired wavelet transforms and support vector machines, achieved diagnostic accuracies exceeding 96% in brain tumor classification (14). In contrast, CT imaging was found to be more limited in distinguishing soft tissue abnormalities, particularly in regions such as the paraventricular and temporal lobes. Our findings corroborate this limitation; MRI revealed a higher frequency of paraventricular lesions (62.5% vs. 17.6%) and frontal-occipital-temporal lesions (60.0% vs. 50.0%) than CT, indicating a higher capacity for spatial localization and lesion delineation.

The theoretical foundation for MRI's enhanced diagnostic performance lies in its superior contrast resolution and its ability to exploit variations in tissue relaxation times, which are critical for identifying heterogeneous tumor microenvironments. Unlike CT, which relies primarily on X-ray attenuation differences, MRI captures detailed tissue architecture using T1, T2, and FLAIR sequences, enabling visualization of edema, necrosis, hemorrhage, and contrast-enhancing tumor margins. These characteristics make MRI particularly effective in differentiating between benign and malignant masses, assessing tumor progression, and planning neurosurgical or radiation interventions (1, 22). Although both modalities effectively detected midline shifts—a marker of mass effect—MRI provided a more comprehensive assessment of cerebral pathology, particularly in complex regions like the brainstem and posterior fossa, where CT is prone to artifacts.

However, the clinical applicability of these findings must be interpreted in light of the study's limitations. The sample size was relatively small ($n=20$), which may limit the generalizability of the findings across broader populations and tumor subtypes. Additionally, the study was conducted at a single tertiary care center using convenience sampling, which introduces selection bias and may not reflect the diagnostic spectrum seen in community or multi-institutional settings. Another limitation is the absence of histopathological confirmation, which could have served as a more definitive reference standard. Moreover, not all patients underwent contrast-enhanced imaging due to contraindications such as allergy risk, potentially affecting the comparative visibility of certain lesions. Furthermore, the lack of blinding between imaging results may have introduced interpretation bias, although standard protocols and structured reporting tools were used to mitigate subjectivity.

Despite these constraints, the study's strengths include its real-world applicability, standardized imaging protocols, and incorporation of advanced statistical analysis, including Chi-square testing and cross-tabulated accuracy metrics. The use of both qualitative assessments and quantitative image features ensures a holistic evaluation of diagnostic performance. These insights are particularly relevant in

resource-limited healthcare environments, where decisions regarding imaging modality selection must be both evidence-based and cost-effective. While CT remains a valuable tool for initial screening and trauma-related assessment, especially where MRI is unavailable or contraindicated, this study underscores the need to prioritize MRI when evaluating suspected brain tumors.

Future research should consider larger, multicenter studies with histological correlation to validate and expand upon these findings. The incorporation of advanced imaging modalities such as perfusion MRI, diffusion tensor imaging (DTI), and MR spectroscopy could further refine tumor characterization and grading. Additionally, integration of artificial intelligence and machine learning techniques in radiological workflows holds promise for enhancing diagnostic precision, particularly in identifying subtle or multifocal lesions (3, 9). Prospective longitudinal studies could also explore the impact of imaging modality on treatment outcomes, recurrence prediction, and survival metrics.

In conclusion, the study substantiates MRI's diagnostic superiority over CT scan in the detection of brain tumors, particularly in terms of sensitivity and lesion localization. These findings align with current literature and support MRI's continued designation as the reference standard in neuro-oncological imaging. While CT retains a role in emergent settings and skeletal assessment, MRI offers unparalleled insights into brain tumor morphology, which are essential for accurate diagnosis, staging, and management planning. Addressing limitations such as sample size and inclusion of histological validation in future studies will be crucial in advancing diagnostic imaging standards and improving patient care in neuro-oncology.

CONCLUSION

This study concluded that magnetic resonance imaging (MRI) demonstrates superior diagnostic accuracy, sensitivity, and specificity compared to computed tomography (CT) in the detection of brain tumors, thereby reaffirming its role as the gold standard in neuroimaging. MRI identified a higher number of intracranial lesions, particularly in the paraventricular and cortical regions, and achieved a sensitivity of 100% and specificity of 80% when compared to CT. These findings underscore the clinical imperative of prioritizing MRI in the diagnostic workup of suspected brain tumors to ensure early and accurate detection, which is critical for timely intervention and improved patient outcomes. For human healthcare, this reinforces the importance of access to advanced imaging modalities in neuro-oncological diagnostics. Future research should expand on these results through larger, multicenter studies with histopathological correlation and explore the integration of emerging technologies such as AI-assisted imaging for enhanced diagnostic precision.

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