JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/9trxzs21

Original Article

Assessment of Tissue Perfusion in Brain Tumor Using CT Perfusion Imaging

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"Cite this Article" **Received**: 11 March 2026; **Accepted**: 26 April 2026; **Published**: 08 May 2026
Author Contributions: EA, AA, AN, AS, SI; Design: EA, AA, AN, AS, SI; Data Collection: EA, AA, AN, AS, SI; Analysis: EA, AA, AN, AS, SI; Drafting: EA, AA, AN, AS, SI..
Ethical Approval: Superior University, Lahore, Pakistan. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: Brain tumor grading is essential for treatment planning and prognosis, but conventional imaging may not fully characterize tumor vascularity and biological aggressiveness. CT perfusion imaging provides functional information through cerebral blood volume, cerebral blood flow, mean transit time, and perfusion score. Objective: To evaluate CT perfusion imaging parameters in patients with brain tumors and assess their association with tumor grade. Methods: This hospital-based analytical cross-sectional study included 100 patients with clinically or radiologically suspected brain tumors. CT perfusion parameters were categorized as normal or abnormal and compared between low-grade and high-grade tumors using chi-square testing. Results: Of 100 patients, 66 had low-grade and 34 had high-grade tumors. Abnormal CBV was observed in 55.9% of high-grade tumors compared with 42.4% of low-grade tumors (p=0.201). Abnormal perfusion score was present in 61.8% of high-grade tumors compared with 45.5% of low-grade tumors (p=0.122). Abnormal CBF and MTT showed minimal differences between groups, with p-values of 0.780 and 0.905, respectively. Conclusion: CT perfusion showed directional trends toward greater perfusion abnormality in high-grade tumors, particularly for CBV and perfusion score, but findings were not statistically significant. CT perfusion may provide adjunctive functional information, but larger studies using continuous parameters are required. Keywords: Brain tumor; CT perfusion; cerebral blood volume; cerebral blood flow; mean transit time; tumor grading.

INTRODUCTION

Brain tumors represent a clinically important cause of neurological morbidity because their biological behavior varies widely according to tumor type, grade, vascularity, and microenvironmental characteristics. Accurate pre-treatment characterization is essential because tumor grade influences surgical planning, biopsy targeting, treatment selection, prognosis, and follow-up strategy. Conventional CT and MRI provide valuable anatomical information, but structural imaging alone may be insufficient to distinguish viable tumor from edema, necrosis, post-treatment change, or biologically aggressive regions within heterogeneous lesions. Since high-grade tumors are commonly associated with angiogenesis, abnormal microvascular proliferation, increased vascular permeability, and altered cerebral hemodynamics, functional imaging techniques that quantify tissue perfusion may provide clinically useful information beyond morphology alone (1).

Computed tomography perfusion imaging is a dynamic contrast-enhanced technique that allows quantitative or semi-quantitative assessment of cerebral blood flow, cerebral blood volume, mean transit time, and related perfusion indices. These parameters reflect tumor vascular supply, capillary transit, and microcirculatory disturbance, which are relevant to tumor aggressiveness and histopathological grade. Previous studies have shown that high-grade gliomas and other malignant intracranial tumors often demonstrate increased CBV and CBF due to neovascularization, while MTT and permeability-related parameters may reflect disorganized vascular architecture and altered blood–brain barrier integrity (1,10,18,19). However, reported diagnostic performance varies across studies because of differences in acquisition protocols, post-processing methods, ROI placement, tumor heterogeneity, and threshold definitions.

The global and regional burden of brain and central nervous system tumors has increased over recent decades, partly because of improved access to neuroimaging and better diagnostic reporting. Epidemiological studies indicate substantial variation in tumor incidence, tumor subtype distribution, and access to advanced diagnostic tools across populations (2–6). In Pakistan and similar resource-limited settings, brain tumor data remain comparatively underdeveloped, and access to advanced MRI-based perfusion or molecular imaging may be limited. CT perfusion therefore has practical relevance because it may provide accessible functional information in centers where CT imaging is more readily available than advanced MRI platforms.

Despite the growing evidence supporting perfusion imaging, important gaps remain. Many studies have focused on selected glioma cohorts, small samples, or advanced imaging environments, while fewer have evaluated CT perfusion parameters in broader local clinical settings using routinely available imaging workflows. In addition, the relationship between categorized perfusion abnormalities and tumor grade requires cautious interpretation because perfusion values may overlap between tumor grades and may be influenced by lesion type, necrosis, edema, ROI selection, and histopathological variability. Therefore, further local evidence is needed to determine whether CT perfusion parameters can serve as supportive adjunctive markers for differentiating low-grade and high-grade brain tumors.

Accordingly, this study was conducted to evaluate CT perfusion imaging parameters, including cerebral blood flow, cerebral blood volume, mean transit time, and perfusion score, in patients with brain tumors and to assess their association with tumor grade. The study hypothesized that high-grade tumors would show a higher frequency of abnormal perfusion parameters than low-grade tumors, reflecting increased vascularity and altered tumor microcirculation.

MATERIALS AND METHODS

This hospital-based analytical cross-sectional study was conducted at General Hospital Lahore over a four-month period after synopsis approval. The study was designed to evaluate the association between CT perfusion imaging parameters and tumor grade among patients with clinically and radiologically suspected brain tumors. A cross-sectional design was selected because the objective was to assess perfusion characteristics and diagnostic grade at a defined point in the clinical evaluation pathway rather than to determine longitudinal progression or treatment response.

A total of 100 patients were included using a convenience sampling technique. The sample size was calculated using a single-proportion formula at a 95% confidence level, an expected proportion of 0.50, and an allowable margin of error of 10%, yielding a required sample of 100 participants. Patients aged 18–70 years of either sex were eligible if they had clinically or radiologically suspected primary or secondary brain tumors, were fit for contrast-enhanced CT perfusion imaging, provided informed consent, and were undergoing biopsy or surgical evaluation where histopathological grading could be obtained. Patients were excluded if they had renal impairment with eGFR below 60 mL/min/1.73 m², pregnancy or lactation, previous allergy to iodinated contrast media, prior brain surgery, radiotherapy, or chemotherapy that could alter tumor perfusion, or inability to complete CT scanning because of severe motion artifact, claustrophobia, clinical instability, or other technical limitations.

After written informed consent, demographic and clinical data were recorded using a standardized data collection form. Variables included age category, gender, cerebral blood flow category, cerebral blood volume category, mean transit time category, perfusion score category, and final diagnosis grade. Diagnosis grade was categorized as low-grade or high-grade according to available clinical-radiological and histopathological assessment. CT perfusion imaging was performed after initial non-contrast CT localization. Patients were positioned supine with the head stabilized to reduce motion artifact. Intravenous iodinated contrast was administered through a cannula using a power injector, followed by dynamic CT perfusion acquisition across the tumor region. Perfusion maps were generated using CT perfusion software, and regions of interest were placed over the tumor and corresponding contralateral normal brain tissue for comparative assessment. Perfusion parameters were categorized as normal or abnormal according to institutional radiological interpretation and perfusion map assessment.

To reduce measurement bias, perfusion assessment was based on standardized ROI placement over tumor tissue and contralateral reference brain tissue. Patients with previous treatment were excluded to minimize confounding from post-surgical, post-radiotherapy, or post-chemotherapy perfusion changes. The use of predefined eligibility criteria also reduced clinical heterogeneity. Data were recorded in coded form to maintain confidentiality and were checked for completeness before entry into the statistical database.

Data were analyzed using SPSS version 27.0. Categorical variables were summarized as frequencies and percentages. The association between diagnosis grade and perfusion categories, including CBV, CBF, MTT, and perfusion score, was assessed using the chi-square test. Gender distribution across tumor grades was also examined using chi-square testing. A p-value below 0.05 was considered statistically significant. Because the available dataset categorized perfusion variables as normal or abnormal, inferential analysis was limited to categorical association testing. All patient records were anonymized before analysis, and collected data were stored securely with restricted access.

Ethical principles were followed throughout the study. All participants were informed about the study purpose, procedure, confidentiality measures, and voluntary nature of participation. Written informed consent was obtained before enrollment. Participants were informed that refusal or withdrawal from the study would not affect their clinical care. Patient identity was protected through coding, and data were used only for research purposes.

RESULTS

A total of 100 patients were analyzed, including 66 low-grade and 34 high-grade brain tumors. The distribution of perfusion abnormalities showed a consistent but statistically non-significant tendency toward higher abnormal perfusion in high-grade tumors. Abnormal CBV was observed in 19/34 high-grade tumors (55.9%) compared with 28/66 low-grade tumors (42.4%), corresponding to an odds ratio of 1.72 (95% CI: 0.75–3.96; p=0.201). Abnormal perfusion score was also more frequent in high-grade tumors than low-grade tumors, affecting 21/34 cases (61.8%) versus 30/66 cases (45.5%), with an odds ratio of 1.94 (95% CI: 0.83–4.51; p=0.122). Abnormal CBF was present in 18/34 high-grade tumors (52.9%) and 33/66 low-grade tumors (50.0%), showing minimal between-group difference (OR: 1.13; 95% CI: 0.49–2.58; p=0.780). Abnormal MTT was similarly distributed between high-grade and low-grade tumors, occurring in 20/34 (58.8%) and 38/66 (57.6%) cases, respectively (OR: 1.05; 95% CI: 0.45–2.44; p=0.905). Gender distribution was also not significantly associated with tumor grade, although males represented 55.9% of high-grade tumors compared with 47.0% of low-grade tumors (OR: 1.43; 95% CI: 0.62–3.29; p=0.398). Overall, CBV and perfusion score demonstrated the strongest directional gradients toward high-grade disease, but none of the tested associations reached statistical significance.

Table 1. Association of Tumor Grade with Perfusion Parameters and Gender

Variable	Low-Grade n/N (%)	High-Grade n/N (%)	Odds Ratio	95% CI	p-value
Abnormal CBV	28/66 (42.4%)	19/34 (55.9%)	1.72	0.75–3.96	0.201
Abnormal CBF	33/66 (50.0%)	18/34 (52.9%)	1.13	0.49–2.58	0.780
Abnormal MTT	38/66 (57.6%)	20/34 (58.8%)	1.05	0.45–2.44	0.905
Abnormal Perfusion Score	30/66 (45.5%)	21/34 (61.8%)	1.94	0.83–4.51	0.122
Male Gender	31/66 (47.0%)	19/34 (55.9%)	1.43	0.62–3.29	0.398

The largest absolute difference between tumor grades was observed for perfusion score, where abnormal values were 16.3 percentage points higher in high-grade tumors than in low-grade tumors. CBV showed the second-largest difference, with abnormal values 13.5 percentage points higher among high-grade tumors. In contrast, CBF and MTT showed only small differences of 2.9 and 1.2 percentage points, respectively. These findings suggest that CBV and composite perfusion score may have greater clinical relevance than isolated CBF or MTT categories in this dataset, although the wide confidence intervals indicate limited precision and insufficient evidence for a statistically significant association.

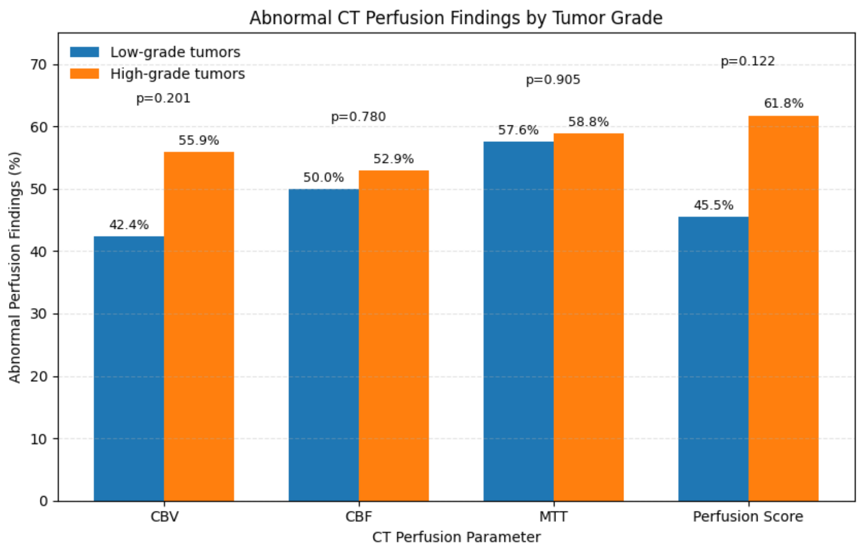

Figure 1. Abnormal CT Perfusion Findings by Tumor Grade. Distribution of abnormal CBV, CBF, MTT, and perfusion score findings among low-grade and high-grade brain tumors, with p-values from chi-square analysis.

High-grade tumors showed a higher frequency of abnormal perfusion findings than low-grade tumors for all assessed CT perfusion parameters. The largest difference was observed in perfusion score, with abnormal findings in 61.8% of high-grade tumors compared with 45.5% of low-grade tumors (p=0.122), followed by CBV abnormalities in 55.9% versus 42.4%, respectively (p=0.201). CBF and MTT showed smaller differences between high-grade and low-grade tumors, with abnormal CBF in 52.9% versus 50.0% (p=0.780) and abnormal MTT in 58.8% versus 57.6% (p=0.905). Although none of the associations reached statistical significance, the higher abnormality rates for CBV and perfusion score suggest a clinically relevant trend toward greater vascular and hemodynamic disturbance in high-grade tumors.

DISCUSSION

The present study evaluated CT perfusion imaging parameters in patients with brain tumors and examined their association with tumor grade. The findings showed a consistent directional trend in which high-grade tumors demonstrated a higher frequency of abnormal CBV and abnormal perfusion score than low-grade tumors. Abnormal CBV was observed in 55.9% of high-grade tumors compared with 42.4% of low-grade tumors, while abnormal perfusion score was present in 61.8% of high-grade tumors compared with 45.5% of low-grade tumors. These findings are biologically plausible because high-grade tumors are commonly characterized by increased angiogenesis, abnormal neovascular architecture, and altered microvascular permeability, which may result in increased perfusion abnormalities on functional imaging (11,18,19).

Although the observed trends support the expected vascular behavior of aggressive tumors, none of the associations reached statistical significance. This may be explained by the limited sample size, categorical transformation of perfusion variables, overlap of perfusion patterns across tumor grades, and possible heterogeneity in tumor histology. Previous studies have reported that relative CBV and CBF are often higher in high-grade gliomas than in low-grade lesions, particularly when continuous perfusion values and normalized ratios are used rather than broad normal/abnormal categories (18,19,23).

Therefore, the non-significant findings in the present study should not be interpreted as absence of biological difference, but rather as insufficient statistical evidence within the available dataset.

The strongest grade-related gradient was observed for perfusion score, followed by CBV, suggesting that composite or blood-volume-based perfusion assessment may be more clinically informative than isolated CBF or MTT categories. This aligns with prior literature indicating that CBV reflects tumor vascular proliferation and may serve as a useful adjunctive marker for tumor grading and biopsy targeting (1,23,35). In contrast, CBF and MTT showed minimal differences between low-grade and high-grade tumors in this study. MTT may be less reliable as an isolated marker because it is influenced by vascular transit delay, necrosis, edema, and regional hemodynamic variability rather than tumor grade alone.

The findings should be interpreted with caution because the study used categorized perfusion variables and did not include continuous perfusion values, receiver operating characteristic analysis, or multivariable adjustment. Future studies should retain continuous CBV, CBF, MTT, and permeability values, calculate normalized tumor-to-contralateral ratios, and compare these parameters directly with histopathological grade. Larger multicenter studies with standardized acquisition protocols, reproducible ROI placement, and observer agreement assessment are needed to determine whether CT perfusion can reliably improve preoperative tumor grading in routine clinical practice.

CONCLUSION

CT perfusion imaging demonstrated clinically plausible trends toward greater perfusion abnormality in high-grade brain tumors, particularly for CBV and composite perfusion score; however, these associations did not reach statistical significance in the present dataset. The findings suggest that CT perfusion may provide supportive functional information regarding tumor vascularity and microcirculatory disturbance, but it should not be used as a standalone method for tumor grading without histopathological confirmation. Larger studies using continuous perfusion measurements, standardized thresholds, and adjusted statistical models are recommended to clarify the diagnostic value of CT perfusion in differentiating low-grade and high-grade brain tumors.

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