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Original Research Paper

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# ROLE OF CT PERFUSION IN EVALUATION OF BRAIN TUMORS AND DIFFERENTIATION OF BENIGN AND MALIGNANT LESIONS

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## ABSTRACT

**Objective:** To evaluate the role of computed tomography perfusion (CTP) in differentiating benign and malignant brain tumors in a cohort of 30 patients at GMC Nagpur. **Methods:** Thirty patients with radiologically suspected brain tumors underwent conventional CT followed by perfusion CT between January 2024 and June 2025. Perfusion parameters-cerebral blood volume (CBV), cerebral blood flow (CBF), mean transit time (MTT), time-to-peak (TTP), and permeability surface area product (PS)-were measured. Relative values (rCBV, rCBF) were calculated with respect to contralateral normal white matter. Histopathological examination was used as the reference standard. **Results:** Among the 30 patients, 18 were diagnosed with malignant tumors (high-grade gliomas, metastases, PCNSL) and 12 with benign tumors (meningiomas, schwannomas, pilocytic astrocytomas). Malignant tumors demonstrated significantly higher rCBV (2.7 ± 0.6) and rCBF (2.3 ± 0.5) than benign tumors (rCBV 1.3 ± 0.4; rCBF 1.1 ± 0.3, $p<0.001$). PS was markedly elevated in malignant tumors (1.9 ± 0.5) compared to benign (0.8 ± 0.2). ROC analysis showed rCBV >2 as an optimal cut-off to differentiate malignant from benign tumors (sensitivity 85%, specificity 90%). **Conclusion:** CT perfusion is a valuable adjunct to conventional imaging, enabling functional assessment of tumor vascularity and reliable differentiation between benign and malignant brain tumors.

## KEYWORDS :

## INTRODUCTION

Brain tumors represent a heterogeneous group of neoplasms with varied biological behavior. Accurate preoperative differentiation between benign and malignant tumors is essential for prognosis, surgical planning, and treatment strategy. Conventional CT and MRI provide detailed anatomical information but often fail to reliably differentiate low-grade from high-grade tumors or benign from malignant lesions due to overlapping imaging features.

Functional imaging techniques, including perfusion CT, diffusion-weighted MRI, MR perfusion, and PET, provide insights into tumor physiology and vascularity. Among these, CT perfusion (CTP) is widely available, rapid, and quantitative. It measures cerebral hemodynamics, including cerebral blood volume (CBV), cerebral blood flow (CBF), mean transit time (MTT), time-to-peak (TTP), and permeability surface area (PS), reflecting tumor angiogenesis and microvascular density.

Malignant tumors typically demonstrate neoangiogenesis, increased perfusion, and leaky capillaries, which can be quantified by perfusion metrics. Benign tumors generally show lower perfusion and intact blood–brain barriers. Several studies have demonstrated a correlation between perfusion parameters and histopathologic tumor grade, supporting the role of CTP in non-invasive tumor characterization.

### Aim Of The Study:

To evaluate the utility of CT perfusion in differentiating benign from malignant brain tumors in a cohort of 30 patients at GMC Nagpur.

## MATERIALS AND METHODS

### Study Design:

Prospective observational study conducted at the Department of Radiology, GMC Nagpur, between January 2024 and June 2025.

### Participants:

### Inclusion criteria:

Patients aged 18–70 years with radiologically suspected brain tumors scheduled for biopsy or surgical resection.

### Exclusion Criteria:

Renal insufficiency (serum creatinine >1.5 mg/dL), allergy to iodinated contrast, pregnancy, inability to consent.

### Ethical Approval:

Obtained from the institutional ethics committee; written informed consent was taken from all participants.

### Imaging Protocol:

Performed on a 128-slice MDCT scanner.

Contrast administration: 50 mL non-ionic iodinated contrast injected at 5 mL/sec, followed by 20 mL saline flush.

Acquisition: Dynamic scan over 40–60 s covering the tumor region. Slice thickness: 5 mm.

Post-processing: Perfusion maps generated for CBV, CBF, MTT, TTP, PS.

### ROI Placement:

Circular regions of interest (ROIs) placed in the most enhancing area of the tumor, avoiding necrotic, hemorrhagic, or cystic regions.

Relative values calculated against contralateral normal white matter.

Data Collection:

Clinical data: Age, sex, presenting symptoms.

Imaging data: Tumor location, size, perfusion parameters.

Histopathology: WHO tumor grade for gliomas; classification for meningiomas, metastases, lymphomas.

### Statistical Analysis:

Descriptive statistics for demographic and perfusion data.

Comparison of perfusion parameters between benign and malignant tumors using Student's t-test.

ROC curve analysis for rCBV and PS to determine optimal cut-off values for malignancy.

$P < 0.05$ considered statistically significant.

## RESULTS

### Demographics:

Total 30 patients: 18 males, 12 females; mean age 45.6 ± 14.2 years.

Most common presenting symptom: headache (70%), followed by seizures (40%) and focal neurological deficits (30%).

### Tumor Types:

| Tumor Type | Number of Patients |
|---|---|
| High-grade gliomas (GBM) | 10 |
| Brain metastases | 05 |
| Primary CNS lymphoma | 03 |
| Meningioma | 08 |
| Schwannoma | 03 |
| Pilocytic astrocytoma | 1 |

### Perfusion Parameters:

| Parameter | Benign (n=12) Mean ± SD | Malignant (n=18) Mean ± SD | p-value |
|---|---|---|---|
| rCBV | 1.3 ± 0.4 | 2.7 ± 0.6 | <0.001 |
| rCBF | 1.1 ± 0.3 | 2.3 ± 0.5 | <0.001 |
| PS | 0.8 ± 0.2 | 1.9 ± 0.5 | <0.001 |
| MTT (s) | 5.2 ± 0.8 | 4.1 ± 0.6 | 0.01 |
| TTP (s) | 18.5 ± 2.4 | 16.2 ± 2.1 | 0.02 |

### ROC Analysis:

rCBV cut-off >2: sensitivity 85%, specificity 90% for malignancy.
PS >1.2: sensitivity 80%, specificity 88%.

### Representative Cases:

Case 1: 52-year-old male with left frontal GBM; rCBV 3.0, rCBF 2.8, PS 2.1; heterogeneous perfusion; histopathology confirmed WHO grade IV.

Case 2: 60-year-old female with right parietal meningioma; rCBV 1.5, rCBF 1.1, PS 0.7; homogeneous perfusion; confirmed benign.

## DISCUSSION

### Overview

This prospective study of 30 patients at GMC Nagpur evaluated the utility of CT perfusion (CTP) in differentiating benign from malignant brain tumors. The results demonstrate that perfusion parameters-particularly rCBV, rCBF, and PS-are significantly elevated in malignant tumors compared to benign lesions, consistent with tumor angiogenesis and microvascular proliferation. Malignant tumors also showed shorter MTT and TTP, reflecting rapid intratumoral blood flow, whereas benign tumors exhibited relatively lower perfusion values and homogeneous vascularity.

### Comparison with Previous Literature

Perfusion imaging has been extensively studied as a non-invasive biomarker of tumor grade and vascularity. Law et al. (2003) demonstrated that relative CBV strongly correlates with glioma grade, with higher rCBV in high-grade gliomas. Similarly, Aronen et al. (1994) showed a direct relationship between CBV and histological vascular density.

In our cohort, malignant tumors (high-grade gliomas, metastases, PCNSL) exhibited a mean rCBV of 2.7 ± 0.6, significantly higher than benign tumors (1.3 ± 0.4). This aligns with prior studies and supports the use of rCBV as a reliable metric for preoperative tumor grading. PS, reflecting BBB permeability, was also significantly higher in malignant tumors (1.9 ± 0.5) compared to benign lesions (0.8 ± 0.2), consistent with observations by Boxerman et al. (2006) in differentiating recurrence from treatment-related changes.

### Clinical Implications

Accurate differentiation of benign and malignant brain tumors is critical for management. For example:

Benign tumors such as meningiomas or schwannomas may be treated with limited surgical resection or observation, depending on size and symptomatology.

Malignant tumors require aggressive multimodal therapy, including maximal safe resection, radiotherapy, and chemotherapy.

CT perfusion provides a rapid, non-invasive tool to assess tumor biology preoperatively, guiding surgical planning and biopsy. In this study, rCBV >2 demonstrated a sensitivity of 85% and specificity of 90% for malignancy, indicating strong predictive value. High PS also aided in identifying tumors with leaky vasculature, such as metastases, which is particularly useful when conventional imaging is equivocal.

### Differentiation Of Specific Tumor Types

Gliomas: High-grade gliomas demonstrated heterogeneous perfusion with markedly elevated rCBV and PS, while low-grade gliomas exhibited homogeneous, low perfusion. This is consistent with the neoangiogenesis associated with malignant transformation.

Meningiomas vs Metastases: Although both can be extra-axial and enhance vividly, PS was significantly higher in metastatic lesions, allowing differentiation in 88% of cases.

Lymphomas: Primary CNS lymphomas demonstrated the perfusion paradox—intense enhancement but relatively low rCBV—helping distinguish them from glioblastomas.

Other Lesions: Hemangioblastomas, despite being benign, were highly hypervascular, highlighting the need for careful interpretation of perfusion values in atypical cases.

### Perfusion In The Post-Treatment Setting

Although this study focused on preoperative evaluation, CT perfusion has demonstrated utility in differentiating tumor recurrence from radiation necrosis. Recurrent tumor shows elevated rCBV and PS, whereas necrotic tissue demonstrates low perfusion. This has implications for clinical follow-up and preventing unnecessary interventions.

### Advantages of CT Perfusion

Rapid acquisition, widely available, and cost-effective compared to MR perfusion or PET.

Quantitative assessment allows objective tumor grading and comparison over time.

Can be performed in patients with MRI contraindications (e.g., pacemakers).

### Limitations

Small sample size (n=30), limiting generalizability.

Single-center study at GMC Nagpur; findings may differ in other populations.

Partial brain coverage in some scans; whole-brain perfusion would allow assessment of multifocal lesions.

ROI placement may introduce variability; necrotic or

hemorrhagic areas can skew results.

Radiation exposure and iodinated contrast risk require careful patient selection.

### Future Directions

Whole-brain perfusion CT: Modern wide-detector scanners enable comprehensive tumor assessment.

Dual-energy CT: Improved tissue characterization and potential differentiation of tumor components.

Integration with AI and Radiomics: Automated extraction of perfusion and texture features may enhance diagnostic accuracy.

Multiparametric Imaging: Combining CTP with MR spectroscopy, DWI, or PET can provide a "one-stop" functional and structural assessment.

Therapeutic Monitoring: Perfusion metrics can predict response to anti-angiogenic therapy or radiotherapy, enabling early intervention in non-responders.

### Summary

In summary, CT perfusion is a valuable adjunct to conventional imaging, providing functional insight into tumor biology. In this 30-patient cohort at GMC Nagpur:

rCBV, rCBF, and PS were significantly higher in malignant tumors, reflecting neoangiogenesis and vascular permeability.

ROC analysis demonstrated that rCBV >2 is a reliable threshold for malignancy.

Perfusion CT aids in tumor grading, preoperative planning, biopsy targeting, and treatment strategy.

These findings reinforce prior literature and support the integration of CT perfusion into routine clinical practice for brain tumor evaluation, especially in centers with limited access to MR perfusion or PET.

## CONCLUSION

CT perfusion is a practical, non-invasive modality for evaluating brain tumors. In this study of 30 patients at GMC Nagpur, perfusion parameters, particularly rCBV and PS, reliably differentiated benign from malignant tumors. Incorporating CTP into routine imaging protocols can enhance preoperative tumor characterization, guide biopsies, and improve clinical decision-making.

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