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DIAGNOSTIC ACCURACY OF MAGNETIC RESONANCE PERFUSION IMAGING IN INTRACRANIAL BRAIN TUMOURS

ABSTRACT

Background

Intracranial tumours are a major global health burden, with high morbidity and mortality. While conventional MRI is the primary imaging tool, it has limitations in grading, treatment assessment, and distinguishing neoplastic from non-neoplastic lesions. Tumour vascularity is a key marker of malignancy, but conventional MRI reflects BBB disruption rather than true angiogenesis.

Dynamic Susceptibility Contrast (DSC) perfusion MRI addresses this gap by evaluating cerebral hemodynamics using T2*-weighted signal changes during contrast bolus transit. Key parameters such as relative cerebral blood volume (rCBV) and flow (rCBF) correlate with tumour grade and aggressiveness. Although used globally, limited regional data exists from South India, necessitating further evaluation.

Objectives

1. To evaluate intracranial tumours using DSC perfusion MRI and quantify rCBV and rCBF.
2. To assess the accuracy of these parameters in distinguishing low- from high-grade gliomas, using histopathology as the gold standard.

Methods

A prospective study was conducted on 35 patients with suspected brain tumours. All underwent conventional and DSC perfusion MRI, followed by histopathological correlation. T2*-weighted perfusion imaging was performed post-contrast, and rCBV/rCBF maps were generated. ROIs were placed over enhancing tumour regions and contralateral white matter to compute relative values. Data was analysed statistically, including ROC analysis.

Results

High-grade gliomas showed significantly elevated rCBV and rCBF compared to low-grade gliomas. ROC analysis demonstrated high sensitivity and specificity with an rCBV cut-off around 1.75. Limitations included susceptibility artefacts and dependency on BBB status.

Conclusion

DSC perfusion MRI is a valuable tool for non-invasive assessment of intracranial tumours. Quantitative parameters like rCBV and rCBF aid in tumour grading, guide biopsies, and enhance diagnostic confidence. Incorporating perfusion imaging into routine MRI protocols improves clinical decision-making, especially in glioma evaluation.

INTRODUCTION

Intracranial tumours represent a significant challenge in modern neuroradiology, accounting for approximately 85–90% of all primary central nervous system (CNS) neoplasms[1]. Globally, over 300,000 new cases are diagnosed annually, with an estimated 250,000 deaths attributed to CNS tumours[2]. In India, brain tumour prevalence ranges from 5–10 per 100,000 people, with over 28,000 new cases and 24,000 deaths reported each year[2].

Magnetic Resonance Imaging (MRI) is the imaging modality of choice for evaluating brain tumours due to its superior soft tissue resolution[3]. However, conventional MRI sequences, while effective for anatomical localisation, often fall short in tumour grading, assessing treatment response, or differentiating between tumour recurrence and post-treatment changes[3]. Additionally, conventional MRI struggles to reliably distinguish neoplastic lesions from non-neoplastic entities such as demyelinating disease, tuberculomas, or subacute infarcts[3].

Angiogenesis plays a central role in tumour growth and malignancy. High-grade tumours are typically characterised by increased neovascularisation[4]. However, conventional contrast-enhanced MRI primarily reflects blood-brain barrier (BBB) disruption rather than actual tumour vascularity[4]. Hence, a more specific imaging technique is needed to evaluate tumour hemodynamics.

Dynamic Susceptibility Contrast (DSC) MRI perfusion is an advanced imaging technique that measures hemodynamic parameters during the passage of a gadolinium-based contrast agent. It utilises T2*-weighted sequences to quantify changes in magnetic susceptibility and derives key parameters such as

relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF)[4]. These values correlate with tumour grade, making DSC perfusion valuable for preoperative grading, prognostication, and treatment planning[4].

DSC perfusion imaging can detect hypervascular areas even in histologically heterogeneous tumours and provide better tumour characterisation than standard post-contrast sequences[4]. Its non-invasive nature and ability to assess microvascular density make it particularly useful when histopathology is delayed or limited by sampling errors[4].

While many international studies support the utility of DSC perfusion imaging in brain tumours, limited data exists from regional Indian populations, particularly in the South Indian context. This study was thus undertaken to evaluate the diagnostic accuracy of DSC perfusion MRI in intracranial tumours and to correlate perfusion parameters with histopathological findings.

By identifying perfusion thresholds and correlating imaging with histopathology, we aim to establish a reliable, non-invasive approach for pre-treatment tumour grading. Early and accurate differentiation between low- and high-grade lesions could significantly impact clinical decision-making and patient outcomes.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Radiodiagnosis at a tertiary care teaching hospital in South India over a period of 18 months. The aim was to evaluate the diagnostic accuracy of dynamic susceptibility contrast (DSC) perfusion MRI in differentiating various types and grades of intracranial tumours, using histopathology as the gold standard.

Study Population

A total of 35 patients presenting with clinical suspicion of intracranial space-occupying lesions (ICSOLs) were recruited. All patients underwent routine MRI along with DSC perfusion imaging. Final histopathological diagnosis was obtained in all cases following surgical excision or biopsy.

Inclusion Criteria

- Patients of any age and gender with suspected primary or metastatic brain tumours.
- Patients willing to undergo contrast MRI and subsequent histopathological evaluation.
- No prior treatment (surgery, radiation, or chemotherapy) for brain tumours.

Exclusion Criteria

- Patients with contraindications to MRI (e.g., pacemakers, metallic implants).
- Allergy or contraindication to gadolinium-based contrast agents.
- Poor image quality due to motion artefacts or technical limitations.

MRI Protocol

All patients were imaged using a 1.5 Tesla MRI scanner. Conventional sequences included axial T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and post-contrast T1-weighted images.

DSC Perfusion Technique

Perfusion imaging was performed using T2*-weighted gradient-echo echo planar imaging (GRE-EPI) during the first-pass of a bolus of gadolinium contrast (0.1 mmol/kg). Data acquisition started simultaneously with contrast injection. A series of images were obtained rapidly to capture signal changes during the passage of contrast through cerebral vasculature.

Post-processing and Analysis

Perfusion maps—rCBV (relative cerebral blood volume), rCBF (relative cerebral blood flow), and MTT (mean transit time)—were generated using vendor-specific post-processing software. Regions of interest (ROIs) were manually placed in the solid enhancing component of the tumour and mirrored in contralateral normal white matter. rCBV values were calculated as a ratio of tumour to normal white matter.

Histopathology Correlation

Histopathological examination served as the reference standard. Tumours were classified and graded according to the WHO 2021 CNS tumour classification.

Statistical Analysis

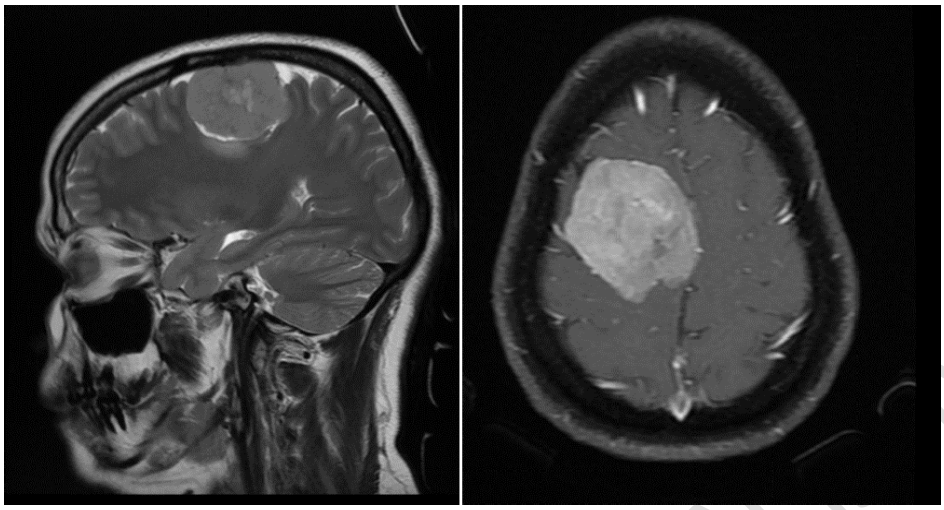
Data were analysed using SPSS software. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for rCBV and rCBF in differentiating high-grade from low-grade gliomas. ROC curves were used to determine optimal cutoff values.

A B

C D

Fig22: AxialFLAIR (A)andsagittalT1+CMRimage(B)show a peripheral ring- enhancing lesion with marked surrounding oedema in a 54-year-old male. ROI at the peripheral enhancing margin of the lesion(C-D)shows a mild fall in signal with a near complete return of curve to baseline. Histopathology:Lymphoma.

A B



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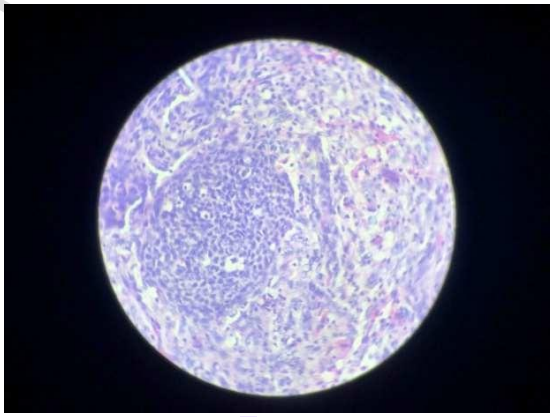
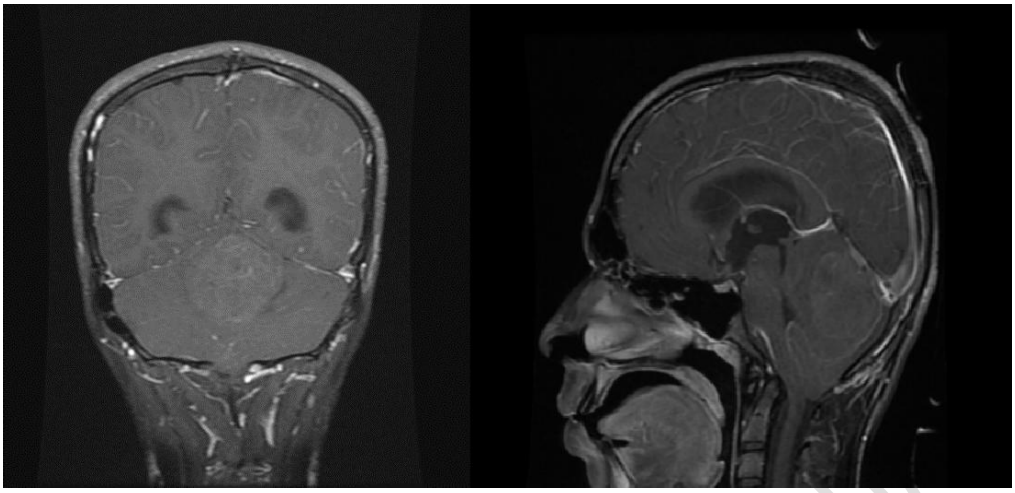


E

Fig 1: Sagittal T2 and axial T1 contrast images in a 35-year-old female. A high convexity dura-based mass in the right frontoparietal area (A) enhances homogeneously on contrast administration (B) ROI at the lesion (C and D) shows a marked signal drop with no return to baseline. Histopathology (E) shows meningiothelial neoplasm with meningiothelial cells arranged in syncytial and fibrous pattern : Transitional Meningioma.

A B



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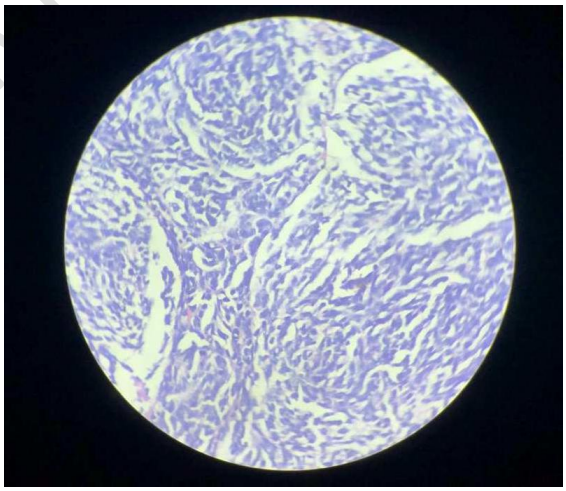

Fig2: Coronalandsagittal T1+C sections of MRI(A-B).A Heterogeneous mildly enhancing lesion in mid-line posterior fossa in a13-year-oldmale. (C-D) shows mild signal drop.Histopathology (E): Medulloblastoma.

RESULTS

This study evaluated perfusion parameters in 35 patients diagnosed with intracranial brain tumours on MRI, comparing findings with histopathological results. The two main perfusion parameters analyzed were relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF).

1. Age and Gender Distribution

Most tumours (65%) occurred in patients aged over 40 years, with a mean age of 42.7 ± 16.4 years. Males constituted 54.3%, and females 45.7% of the study population.

2. Tumour Location

Of the 35 cases, 54.3% were intra-axial, and 45.7% were extra-axial tumours.

3. Extra-axial Tumours

Among extra-axial tumours, meningiomas (68.75%) were more common than schwannomas (31.25%).
Mean rCBV was significantly higher in meningiomas (5.57) compared to schwannomas (4.07) ($p = 0.002$).
Mean rCBF was also higher in meningiomas (2.96) than in schwannomas (2.60), but this was not statistically significant ($p = 0.258$).

4. Adult Intra-axial Tumours

These included high-grade gliomas (53.3%), low-grade gliomas (40%), and lymphomas (6.7%).
High-grade gliomas showed significantly higher perfusion values:
rCBV: 5.75 ± 0.91 vs. 2.83 ± 1.84 in low-grade gliomas ($p = 0.010$)
rCBF: 3.41 ± 1.10 vs. 1.60 ± 0.94 ($p = 0.006$)

5. Diagnostic Accuracy

rCBV cut-off of 5.15 yielded:
Sensitivity: 75%
Specificity: 83.3%
PPV: 85.7%, NPV: 71.4%
AUC: 0.917 ($p = 0.010$)
rCBF cut-off of 2.25 yielded:
Sensitivity: 87.5%
Specificity: 83.3%
PPV & NPV: 87.5%, 83.3% respectively
AUC: 0.906 ($p = 0.012$)

These findings demonstrate the diagnostic utility of perfusion MRI, especially rCBV and rCBF, in distinguishing between high- and low-grade gliomas.

6. Pediatric Tumours

Among 4 pediatric patients, high-grade embryonal tumours showed the highest perfusion values (rCBV: 4.8, rCBF: 3.8). Medulloblastoma and pilocytic astrocytoma showed moderate values in a comparable range.

DISCUSSION

This study examined the utility of Dynamic Susceptibility Contrast (DSC) MRI perfusion parameters—relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF)—in evaluating brain tumours, with histopathology as the reference standard.

Extra-Axial Tumours

Among extra-axial tumours, meningiomas demonstrated higher rCBV values compared to schwannomas (mean 5.57 vs. 4.07; $p = 0.002$). The increased rCBV correlates with the known hypervascular nature of meningiomas and their strong vascular stroma, which has been supported in previous perfusion studies[5].
Although rCBF values were slightly higher in meningiomas (2.96 vs. 2.60), this difference was not statistically significant ($p = 0.258$), implying that rCBV is a more reliable perfusion marker in evaluating these tumours[5].

Intra-Axial Tumours – Gliomas

The perfusion parameters rCBV and rCBF effectively distinguished high-grade from low-grade gliomas. High-grade gliomas showed significantly increased rCBV (5.75 vs. 2.83; $p = 0.010$) and rCBF (3.41 vs. 1.60; $p = 0.006$), consistent with literature linking increased angiogenesis and neovascularisation to tumour aggressiveness[6,7].

ROC analysis identified a cut-off value of rCBV > 5.15, achieving 75% sensitivity and 83.3% specificity. For rCBF, a cut-off >2.25 yielded 87.5% sensitivity and 83.3% specificity. These findings agree with multiple meta-analyses demonstrating rCBV as a strong predictor for glioma grading, with pooled sensitivity and specificity exceeding 90% and 80%, respectively[8,9].

Though rCBF is less widely adopted than rCBV, several studies support its complementary role, particularly when interpreted alongside morphological and spectroscopic data[10]. However, perfusion metrics may be influenced by tumour heterogeneity, necrosis, and susceptibility artefacts, making consistent ROI placement and technical standardisation critical[11].

Paediatric Tumours

In paediatric patients, high-grade embryonal tumours displayed higher rCBV and rCBF compared to medulloblastomas and pilocytic astrocytomas. These observations are consistent with prior reports showing increased perfusion in aggressive childhood CNS tumours[12]. Due to limited sample size, however, definitive conclusions remain tentative.

STRENGTHS AND LIMITATIONS

The study's strength lies in its correlation with histopathology and inclusion of both intra- and extra-axial tumours across age groups. Nonetheless, limitations include a small sample size, particularly among paediatric and low-frequency tumour subtypes, and lack of molecular profiling (e.g., IDH mutation, 1p/19q codeletion), which is increasingly relevant in glioma classification[13].

Perfusion imaging is also susceptible to errors due to contrast leakage, artefacts, and imprecise tumour ROI selection, especially in heterogeneous lesions. Advanced methods such as leakage correction algorithms and automated segmentation tools could improve accuracy in future studies[14].

CONCLUSION

Our findings demonstrate that DSC perfusion MRI, particularly rCBV, is an effective non-invasive tool for assessing brain tumour vascularity and grading. Significant differences in rCBV and rCBF values between high-grade and low-grade gliomas, and between meningiomas and schwannomas, were observed.

rCBV showed statistically significant accuracy in differentiating tumour grades and types.

rCBF also contributed useful diagnostic information, with higher sensitivity in glioma grading.

Cut-off values of rCBV >5.15 and rCBF >2.25 were found effective in differentiating high- from low-grade gliomas.

Given its diagnostic utility, DSC perfusion MRI should be integrated into routine MRI protocols for brain tumour evaluation. This modality can assist with biopsy targeting, pre-operative planning, and treatment monitoring. However, future studies with larger cohorts and molecular correlations are essential to strengthen and standardise these findings.

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