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Role of perfusion weighted imaging in the differential diagnosis of intracranial space occupying lesions

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ABSTRACT

Introduction. Magnetic Resonance Imaging (MRI) is a well-established modality for identifying intracranial space-occupying lesions (ICSOLs). However, conventional MRI has limitations in the cerebral glioma accurate grading. Advanced techniques, like Diffusion-Weighted Imaging (DWI), Perfusion MRI, and Magnetic Resonance Spectroscopic Imaging (MRS), have been introduced to address these limitations.

Aims and objective. The primary objective of this research is to assess the significance of perfusion-weighted imaging (PWI) in distinguishing intracranial space-occupying lesions (ICSOLs), with a specific emphasis on its capacity to refine diagnostic accuracy and advance the classification of cerebral gliomas.

Materials and methods. A prospective observational research involving 38 patients having ICSOLs used a Philips Multiva 1.5 Tesla MRI system. The protocol included DWI, ADC (Apparent Diffusion Coefficient) analysis, and perfusion imaging.

Results. The study population (n=38) had a diverse age range (22-70 years), with a majority in the 30-40 age group. High-grade gliomas constituted 43.2% of all the cases. Significant differences in rCBF, rCBV, and MTT have been observed among HGGs & LGGs. Specific cut-off values were used to predict glioma grades.

Discussion. Comparisons with existing studies validated these findings, emphasizing the utility of advanced physiological techniques in enhancing diagnostic precision. Discrepancies with certain studies have highlighted the need for a comprehensive approach to lesion characterization.

Conclusion. Intracranial lesion diagnosis, especially for meningiomas, demonstrated comparable efficacy between conventional and advanced techniques. While conventional MRI can differentiate lower-grade from higher-grade gliomas to a limited extent, the combination of advanced physiological approaches significantly improves specificity in tumor categorization.

Keywords: magnetic resonance imaging, perfusion, intracranial space occupying lesions, radiology

INTRODUCTION

MRI is a well-established modality for optimal identification and classification of intracranial space-occupying lesions. Conventional MRI with advanced physiological techniques helps with comprehensive morphological and chemical analysis of intracranial space-occupying lesions, thereby providing a better diagnostic definition.

The most significant & prevalent type of main brain tumor is cerebral glioma [1]. Sufficient glioma grading is critical because different tumor grades have different clinical outcomes and prognoses. However, conventional MRI is not always able to determine glioma grade with sufficient accuracy. Consequently, several sophisticated MRI techniques have been developed for glioma grading [2,3]. Diffusion-weighted imaging (DWI) offers important details about the cellularity and extracellular spaces within tumors and is frequently used to grade gliomas [4]. Cell density and several proliferation parameters are negatively correlated with

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the ADC acquired from DWI [4–6]. Additionally, there is a considerable difference in the ADC between HGGs (high-grade gliomas) and LGGs (low-grade gliomas) [6].

Although MRI offers superior contrast for soft tissues, its ability to identify tumor type as well as grade with specificity & sensitivity is limited [7]. In addition to the anatomical information gathered with traditional MRI, MRS offers metabolic information about the tissue under investigation [8]. As a result, MRS has been suggested as a substitute for brain tumor grading [9]. Appropriate adjustments to data gathering and spectroscopic localization techniques are necessary for dependable MRS operation [10].

Perfusion MRI offers insights into microcirculation, *in vivo* tumorigenesis, and tissue vascularization. Perfusion MRI provides information on tissue oxygenation, flow of blood, and volume of blood. The parameters of MTT, rCBF, and rCBV are derived from signal variations in the arteries and veins that happen at the time of the passage of a paramagnetic contrast agent [11].

When seeded over the whole brain, tractography data consists of several hundreds of thousands of trajectories, or "fibers". Currently, a trained expert should interactively select a specific fiber tract of interest to determine its location specific to a patient. Multiple regions of interest must be placed in positions determined by the anatomy of the patient during the selection process [12–14].

REVIEW OF LITERATURE

MRI is a well-established modality for optimal identification and classification of intracranial space-occupying lesions. Conventional MRI with advanced physiological techniques helps with comprehensive morphological and chemical analysis of intracranial space-occupying lesions, thereby providing a better diagnostic definition.

Dynamic susceptibility contrast imaging (DSCI) measures perfusion MR imaging captures the initial passage of an intravenous injection of a magnetic contrast agent very quickly, usually via echo planar imaging (EPI). Hemodynamic parameters like CBF, CBV, and MTT could be obtained via kinetic analysis of these data. This offers a valuable addition to structural imaging in various diseases and a non-invasive, radiation-free substitute for traditional methods of assessing tissue perfusion, including stable Xe-CT ("Xenon-enhanced Computed Tomography"), SPECT ("Single-Photon Emission Computed Tomography") and PET ("Positron Emission Tomography").

Sonay Aydin et al observed that rCBV values of HGGs & LGGs were in the range of 2.41+/-0.55 and 5.48+/-0.72 respectively. They also concluded rCBF of HGGs & LGGs were in range of 2.46+/-0.57 and 5.1+/-1.21 [15].

Contrast mechanisms

To use tracer kinetic analysis to extract hemodynamic parameters by dynamic MRI, it is required to know the concentrations of the contrast agent in different tissue compartments. Therefore, the relationship between the observed signal variations at the time of the contrast agent bolus passage and the associated concentration is crucial for specific pulse sequences (such as spin-echo, or gradient-echo, SE, GE EPI).

The study of contrast mechanisms in biological tissues is complex and continues to be an active field of research. In the following sections, the findings of importance to the application and understanding of perfusion imaging are described in detail.

Susceptibility contrast: The most popular method for performing cerebral perfusion imaging (DSCI) is to use a T2 SE or T2-weighted GE sequence (typically EPI) to follow the passage of a paramagnetic gadolinium (Gd)-based chelate that is quickly injected. The brain experiences signal loss due to the spins dephasing as they diffuse amongst large, microscopic susceptibility gradients created by the contrast agent intravascular compartmentalization, which results in zero 1st -pass extraction of the agent while the BBB ("Blood-Brain Barrier") is reasonably intact.

MATERIALS AND METHODS

This prospective observational study has been performed in our department after obtaining approval by the ethics committee. Patients referred for investigational procedures who were found to have ICSOL detected on CT or MRI were included.

Magnetic resonance imaging protocol: First, the Magnetic Resonance technique was explained to selected patients. A thorough clinical history was recorded. Written informed consent was obtained and prior medical records were obtained. Subsequently, patients were positioned and checked for metallic objects. MRI findings in techniques including DWI, perfusion imaging, and ADC are correlated with the final diagnosis (using HPE).

Magnetic resonance imaging ("MRI, PHILIPS MULTIVA 1.5 TESLA MRI") utilizing 16-channel head coils

Position: Supine position
Orientation: Headfirst
Coil: Head coil

To perform MRI PHILIPS MULTIVA 1.5 TESLA MRI with the following sequences: diffusion-weighted imaging, ADC sequence, axial T2 (coronal and sagittal), FLAIR coronal and axial, 3D T1 sequences, and perfusion imaging.

Inclusion criteria

- Patients with ICSOLs detected/ Computed tomography or Magnetic resonance imaging.
- Patients who have a final definitive diagnosis/ Histopathological result available.

Exclusion criteria

- Patients with cochlear implants, prosthetic heart valves, cardiac pacemakers, or metallic implants were also excluded.
- The patient has a past with claustrophobia.
- Every patient who declines to participate in the research.

Benefits

It provides non-invasive non-ionizing diagnostic possibilities in ICSOLs, further contributing to better evaluation and management of the patient.

Potential risks

- A gadolinium contrast medium has been generally safer. Side effects along with reactions have been unusual but can occur.
- Transient reactions - headache, nausea and dizziness
- Allergy-like reactions
- Nephrogenic systemic fibrosis

Limitations of the study

Claustrophobic patients with implanted electronic devices may not be able to undergo MRI examinations.

RESULTS

Individuals aged 22 -70 yrs have been involved in this research. The participants' mean age in the research was 43.49 with an SD of 12.89. Most of them belonged to the age group of 30 – 40 yrs (40.5%), and the least were older than 60 years (8.1%). In the study group, 22 (59.5%) have been men & 15 (40.5%) have been women.

The majority of the patients in study group had HGGs (43.2%), 21.3% had low-grade gliomas, 28% had meningiomas, 5.4% had neuroglial cysts, and 2% had hemangioblastomas on HPE.

There have been major variations in rCBF among HGG and LGG groups (p <0.05, Mann–Whitney U test). The mean rCBF value of the HGG (3.69) was higher than that of the LGG (1.61) (Table 1).

There have been major variations in rCBV among HGG and LGG (p <0.05, Mann–Whitney U test). The mean rCBV value for HGG (6) was higher than that for LGG (2.46) (Table 2).

There have been major variations in MTT among HGG and LGG, with a p-value <0.05 (Mann-Whitney U test). The mean MTT value for HGG (1.70) was lower than that for LGG (1.99) (Table 3).

An rCBF value of > 2.66 has been observed to predict HGGs having 80% sensitivity & 87.5% specificity (AUC: 0.813; p=0.015) (Table 4 and Figure 1).

TABLE 1. Comparison of rCBF between HGG and LGG

HPE	Mean±SD	Median	Minimum-Maximum	p value
HGG	3.69±1.30	4.10	1.10–4.60	0.013
LGG	1.61±1.17	1.20	1.10–4.50	

TABLE 2. Comparison of rCBV between HGG and LGG

HPE	Mean±SD	Median	Minimum-Maximum	p value
HGG	6.00±1.90	6.90	2.40–7.60	0.008
LGG	2.46±0.19	2.45	2.22–2.80	

TABLE 3. Comparison of MTT between HGG and LGG

HPE	Mean±SD	Median	Minimum-Maximum	p value
HGG	1.70±0.22	1.64	1.36–2.20	0.003
LGG	1.99±0.08	2.00	1.86–2.10	

TABLE 4. Cut-off value,sensitivity and specificity

Variables	Cut-off value	Sensitivity	Specificity	AUC	p value
rCBF	2.66	80	87.5	0.813	0.015
rCBV	4.3	80	100	0.888	0.003
MTT	1.83	100	80	0.842	0.088

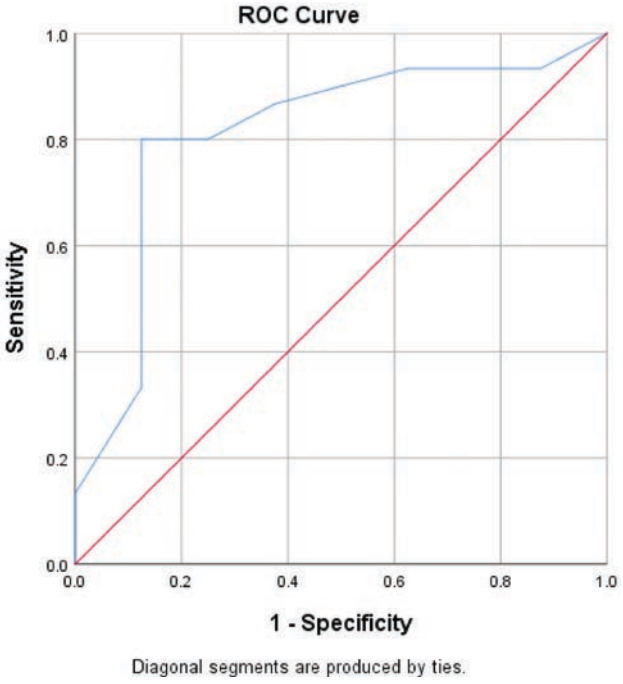

FIGURE 1. ROC curve for rCBF

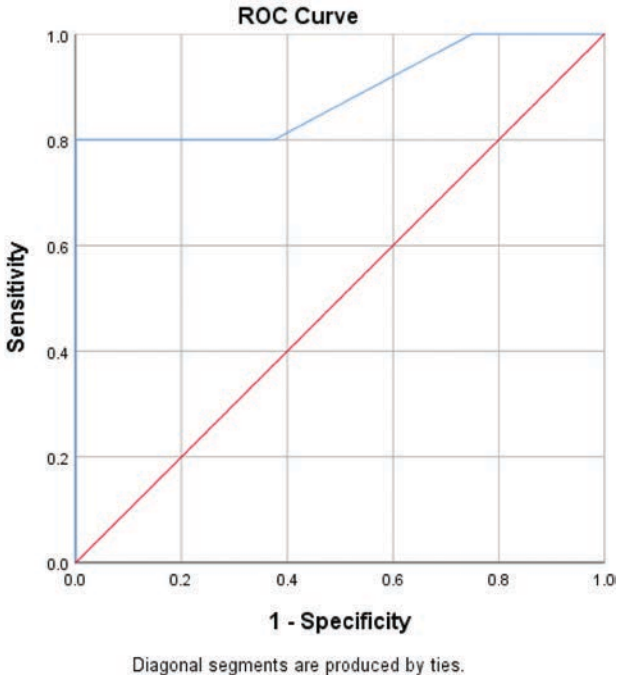

FIGURE 2. ROC curve for rCBV

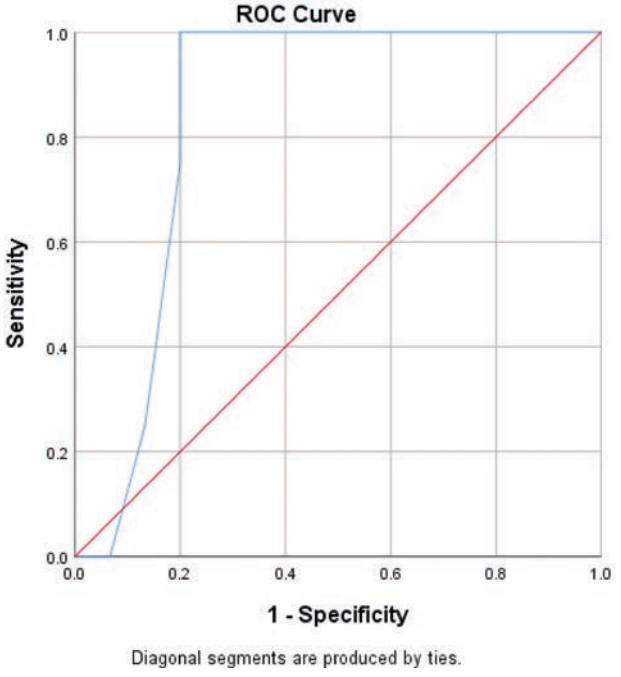

FIGURE 3. ROC curve for MTT

A r CBV value of >4.3 has been observed to predict HGGs with 80% sensitivity & 100% specificity (AUC: 0.888; p =0.003) (Table 4 and Figure 2).

An MTT value of > 1.83 has been observed to predict LGGs with 100% sensitivity & 80% specificity (AUC: 0.842; p =0.08) (Table 4 and Figure 3).

DISCUSSION

Our prospective study included 38 patients who were referred for MRI after being diagnosed with intracranial space-occupying lesions and had a final definitive diagnosis/histopathological results.

The majority of them belonged to the age group of 30–50 yrs (51.3%). However, the age at presentation varied widely between 22-70 years. Most patients presented with seizures and headaches, with few presenting with hemiparesis/hemiplegia.

After routine investigations, including CT, the patients were subjected to MRI and contrast was given and processed with perfusion imaging, which included rCBV, rCBF, and MTT. DWI was performed (TR-4200 and TE- 140 ms and b-value of 1000), and ADC values have been computed by placing an ROI of area 20 +/-100 mm2.

Perfusion MRI of the lesion was performed after reference mapping of the ipsilateral middle cerebral artery.

The mean rCBF values of LGGs & HGGS were found to be 1.61+/-1.1 and 3.7 ± 1.3, correspondingly, and the mean rCBV of LGGs & HGGs has been observed to be 2.46/- 0.19 & 6 ± 1.9, respectively.

These findings correlate with those of a study by Sonay Aydin et al., who found that rCBV values of LGGs and HGGs have been in the range of 2.41/- 0.55 and 5.48+/- 0.72 respectively. They also concluded rCBF of LGGs & HGGs were in the range of 2.46+/-0.57 and 5.1+/- 1.21 [15].

In another study conducted by Meng Law, Stanley Yang et al. depicted that rCBV values of LGGs and HGGs were in the range of 2.1+/-1.6 and 5.2± 3.2 [16], which correlated well with our research.

In a study conducted by ItaloAprile et al., there has been no major variation among LGGs and HGGs. However, this study did not concur with the findings of the present study [17].

Bahattin-Hakyemez conducted another study which revealed that the rCBF and rCBV ratios in high-grade gliomas were 3.32+/-1.87 and 6.50+/-4.29, respectively. The rCBF and rCBV ratios in low-grade gliomas were 1.16+/- 0.38 and 1.69+/-0.51, respectively [18]. Higher values were observed when comparing LGGs and HGGs; however, the mean values from this study and our study differed.

CONCLUSION

In the case of meningiomas, conventional techniques were at par in diagnosis when compared to advanced physiological techniques.

Using conventional MRI techniques, we were able to diagnose brain tumors (from infectious and other conditions, such as demyelinating disorders). Conventional MRI techniques can also differentiate LGGs and HGGs to a lesser extent than advanced physiological techniques, which have higher specificity in the categorization of lower- and higher-grade tumors.

Hence, advanced physiological techniques can be routinely employed in patients having intracranial space-occupying lesions. The value added by advanced physiological techniques is useful in determining the benignity or aggressiveness of the tumor when used along with conventional approaches.

Declaration of patient consent:
The authors affirm that they have secured all necessary patient consent.

Competing interests:
There are no disclosed conflicts of interest, either financial or non-financial.

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