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ROLE OF DIFFUSION-WEIGHTED IMAGING IN THE EVALUATION OF INTRACRANIAL LESIONS

N. Shiva Prasath *, B. Spavan and R. Praveen

Department of Radiology, Sri Siddhartha Medical College, Tumkur - 572107, Karnataka, India.

Keywords:

Diffusion weighted imaging (DWI), Apparent diffusion coefficient (ADC), Intracranial lesions, Braintumors, perilesional edema, Supratentorial lesions, Infratentorial lesions, WHO grades, Diagnostic accuracy, Neuro-oncology

Correspondence to Author:
Dr. N. Shiva Prasath

Junior Resident,
Department of Radiology,
Sri Siddhartha Medical College,
Tumkur - 572107, Karnataka, India.

E-mail: shiva.prasath35@gmail.com

ABSTRACT: This study investigates the diagnostic utility of Diffusion Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) values in evaluating intracranial lesions. A cross-sectional analysis of 44 patients was conducted, examining age and gender distribution, histopathological types, and grades of brain tumors. The highest proportion of individuals (22.7%) was within the 0-10 age range, with males comprising 56.8% of the sample. The study focused on supratentorial and infratentorial lesions, categorized by WHO grades, highlighting that Grade IV lesions were most common in both regions. High-grade tumors (WHO Grade III and IV) demonstrated lower ADC values, indicating restricted diffusion, while non-neoplastic conditions such as arachnoid and epidermoid cysts exhibited higher ADC values, reflecting increased diffusion. The presence of perilesional edema was more frequent in higher-grade tumors, underscoring their aggressive behavior and impact on surrounding brain tissue. Diffusion restrictions were significant in Grade IV lesions, with both partial and complete restrictions observed. The Receiver Operating Characteristic (ROC) curve analysis revealed an Area under the Curve (AUC) of 0.70, indicating that DWI possesses moderate accuracy in distinguishing between high-grade and low-grade brain tumors. The scatter plot of diagnoses versus ADC values illustrated the heterogeneity of diffusion characteristics among different tumor types, aiding in the differentiation of malignant and benign conditions. Our findings emphasize the importance of incorporating DWI and ADC measurements into routine MRI evaluations, enhancing diagnostic precision and prognostic prediction.

INTRODUCTION: Diffusion-weighted imaging constitutes an advanced MRI method relying on the random motion of water molecules inside and across intracellular and extracellular environments. It delivers distinctive biological and clinically significant data regarding the tissue structure and architectural arrangement.

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Image contrast in diffusion-weighted imaging differs significantly from standard MRI methods, as it depends on the molecular movement of water, which is notably modified in pathological conditions. DWI holds primary significance in brain imaging due to its high sensitivity in detecting strokes, which represents one of the crucial differential diagnoses in almost all patients presenting with a neurological issue [1].

It is extremely beneficial in distinguishing acute stroke from other conditions that may present with sudden neurological deficits. DWI is a highly valuable sequence for detecting hyper acute stroke, which might be overlooked in traditional MRI

sequences. Besides its role in stroke, DWI offers additional information in various cerebral disorders, such as tumors, intracranial infections, traumatic brain injury and demyelinating diseases. Since DWI aids in identifying hyperacute and acute strokes and provides supplementary data in other cerebral disorders, it is a crucial MR imaging sequence and should be included in all examinations. This study aims to evaluate the role of Diffusion Weighted Imaging in assessing various intracranial lesions [2].

Intracranial lesions, a diverse array of abnormalities inside the cranial cavity, pose significant challenges in clinical practice due to their varied origins, complex pathophysiology, and potentially devastating outcomes. These lesions include a range of conditions, such as tumors, cysts, abscesses, hemorrhages, and vascular malformations, each with unique characteristics and management considerations. Medical research in this field is crucial for advancing our understanding of intracranial lesions and improving diagnostic precision, treatment effectiveness, and patient outcomes. The causes of intracranial lesions are multifactorial, with various elements contributing to their development, including traumatic brain injuries, infections, inflammatory processes, vascular abnormalities, and neoplastic growth. Trauma can cause intracranial hemorrhage, contusions, and hematomas, while infections like meningitis or brain abscesses result from microbial invasion.

Neoplastic processes, including primary brain tumors or metastatic lesions from distant cancers, represent a significant subset of intracranial lesions, arising from different cell types within the brain. The pathophysiology of intracranial lesions varies based on their underlying cause and location within the brain. Tumors may disrupt normal neuronal function by exerting mass effects, invading surrounding tissues, or causing increased intracranial pressure. Vascular lesions, such as arteriovenous malformations (AVMs), can lead to hemorrhage or ischemia due to abnormal blood flow patterns. Inflammatory or infectious lesions often trigger an immune response, resulting in tissue damage and edema. Accurate diagnosis of intracranial lesions is essential for appropriate management and prognosis. Imaging techniques such as magnetic resonance imaging (MRI), computed tomography (CT), CT angiography (CTA), magnetic resonance angiography (MRA), and positron emission tomography (PET) play a central role in the diagnostic process, allowing clinicians to visualize the size, location and characteristics of the lesion. Histopathological analysis remains the gold standard for definitive diagnosis, particularly in cases of suspected neoplastic or infectious lesions, guiding treatment decisions and prognostic assessments.

The management of intracranial lesions depends on their specific etiology, location, and clinical presentation, often requiring a multidisciplinary approach involving neurosurgeons, neurologists, oncologists, and radiation oncologists to develop individualized treatment plans. Surgical resection, adjuvant therapies such as radiation therapy or chemotherapy, minimally invasive techniques, and immunotherapy are among the treatment modalities used to address intracranial lesions, aiming to optimize patient outcomes and reduce the burden of these challenging neurological conditions [3, 4, 5]. Diffusion-weighted imaging (DWI) is a sophisticated magnetic resonance imaging (MRI) method that offers valuable insights into the microstructural properties of tissues based on the random movement of water molecules. Unlike traditional MRI sequences, DWI utilizes the Brownian motion of water molecules to produce contrast, providing unique information about tissue composition and pathology [6].

In DWI, images are captured with sensitivity to the movement of water molecules within tissues. Water diffusion is naturally influenced by tissue microstructure, including cellular density, membrane integrity, and tissue arrangement. In areas with high cellular density or restricted diffusion, such as in tumors or zones of acute ischemia, water molecules show reduced diffusion rates, resulting in higher signal intensity on DWI images. Conversely, in areas with more freely diffusing water molecules, such as in cerebrospinal fluid (CSF) or regions of chronic infarction, signal intensity on DWI images is lower [7]. The aim of the study is to assess the role of diffusion-weighted imaging (DWI) in the evaluation of intracranial lesions. The objectives are to describe and study the features of intracranial lesions on DWI and to

compare these DWI features with other imaging sequences to aid in differentiating various types of lesions.

MATERIALS AND METHODS:

Study Setting and Design: The study was conducted at the Department of Radiodiagnosis, Sri Siddhartha Medical College & Research Centre, Tumkur, over a period of 24 months. This cross-sectional study aimed to describe the features of intracranial lesions on diffusion-weighted imaging (DWI) and compare these features with apparent diffusion coefficient (ADC), T2, FLAIR, and other sequence images. A purposive sampling method was used to select patients with intracranial lesions detected on MRI of the brain.

Study Population: The patients recruited in the study are those presenting to the Department of Radiodiagnosis at Sri Siddhartha Medical College for MRI brain examinations. The study included 44 patients with clinical and routine MR imaging/CT evidence of intracranial lesions. These patients had undergone MRI scans utilizing a SIEMENS 1.5 tesla MR scanner. The MRI scans were conducted based on the advice of the referring physician, and no patient was subjected to MRI solely for the purpose of this study.

Inclusion Criteria:

A. Patients referred to the Department of Radiodiagnosis for MRI to investigate any intracranial lesions.

B. Patients with CT findings indicative of or suspicious for intracranial lesions.

C. Patients clinically referred to diffusion-weighted MRI of the brain who are found to have intracranial lesions.

Exclusion Criteria:

A. Patients who are uncooperative, unwilling to participate, or claustrophobic.

B. Patients with contraindications for undergoing MRI scans, such as those with pacemakers, cochlear implants, or cerebral artery aneurysm clips.

Data Analysis: A cross-sectional study was conducted over the next 24 months. Information collected from the semi-structured pro-forma was analyzed and documented. Data was entered into an Excel spreadsheet.

Descriptive statistical analysis was performed using mean and standard deviation for quantitative variables, and frequency and percentages for categorical variables. The analysis was carried out using SPSS version 29.0.1.

RESULTS: Age and Gender Distribution: reveals that the highest proportion of individuals (22.7%) falls within the 0-10 age range, followed by a notable distribution in the 40-50 age range (20.5%). There is a significant drop in the 10-20 and 20-30 age ranges, with 11.4% and 9.1% respectively.

The 30-40 and 50-60 age intervals see an increase again, with 18.2% and 15.9% respectively. The lowest frequency is observed in the 60-70 age interval, accounting for only 2.3% of the population. This distribution indicates a higher concentration of younger individuals and those in their middle age, with fewer older adults. The gender distribution with 56.8% males and 43.2% females based on a hypothetical count from the data provided.

TABLE 1: HISTOPATHOLOGICAL TYPE AND GRADE OF THE DIFFERENT INFRATENTORIAL TUMORS AND THEIR MEAN ADC VALUE

Diagnosis	Who Grade	Mean ADC	Range ADC
Anaplastic Ependymoma	III	1.010000	0.00
Arachnoid Cyst	Non-Neoplastic	3.100000	0.00
Atrt	IV	0.640000	0.00
Bithalamic Glioma	IV	0.760000	0.00
Chorid Plexus Carcinoma	III	0.880000	0.00
Craniopharyngioma	I	2.000000	0.00
Demyelination	Non-Neoplastic	1.450000	0.50
Diffuse Midline Glioma	IV	1.155000	0.43
Embryonal Tumour	IV	0.750000	0.00

Ependymoma	II	0.955000	0.09
Epidermoid Cyst	Non-Neoplastic	1.625000	1.35
Gbm	IV	0.634000	0.38
High Grade Glioma	IV	0.716667	0.21
Intraventricular Meningioma	II	4.200000	0.00
Juvenile Pilocytic Astrocytoma	I	1.505000	0.07
Lymphoma	IV	0.480000	0.00
Medulloblastoma	IV	0.680000	0.48
Meningioma	II	1.902500	3.38
Metastasis	IV	0.990000	0.62
Ncc (Colloid Vesicular Stage)	Non-Neoplastic	1.360000	0.00
Oligodendroglioma	II	1.250000	0.00
Oligodendroglioma	III	1.310000	0.58
Optic Nerve Sheath Meningioma	II	0.790000	0.00
Pyogenic Abscess	Non-Neoplastic	0.380000	0.00
Sega	I	1.090000	0.00
Supratentorial Ependymoma	III	0.930000	0.00

Table 1 provides a detailed overview of the histopathological types and grades of various infratentorial tumors along with their corresponding mean ADC (Apparent Diffusion Coefficient) values and ranges. The table indicates that non-neoplastic conditions like "Arachnoid Cyst" and "Epidermoid Cyst" have high mean ADC values of 3.1 and 1.625 respectively, reflecting its less cellular and benign nature. In contrast, high-grade tumors such as "ATRT" (0.64), "GBM" (0.634), and "Lymphoma" (0.48) exhibit significantly lower mean ADC values, suggesting restricted diffusion and high cellular nature typical of malignant tumors. Intermediate ADC values are seen in lower-grade tumors and certain non-neoplastic conditions, for example, "Juvenile Pilocytic Astrocytoma" (1.505) and "Demyelination" (1.45). The range of ADC values, where available, further highlights the variability within each diagnostic category, emphasizing the diagnostic utility of ADC measurements in differentiating between various types of brain lesions.

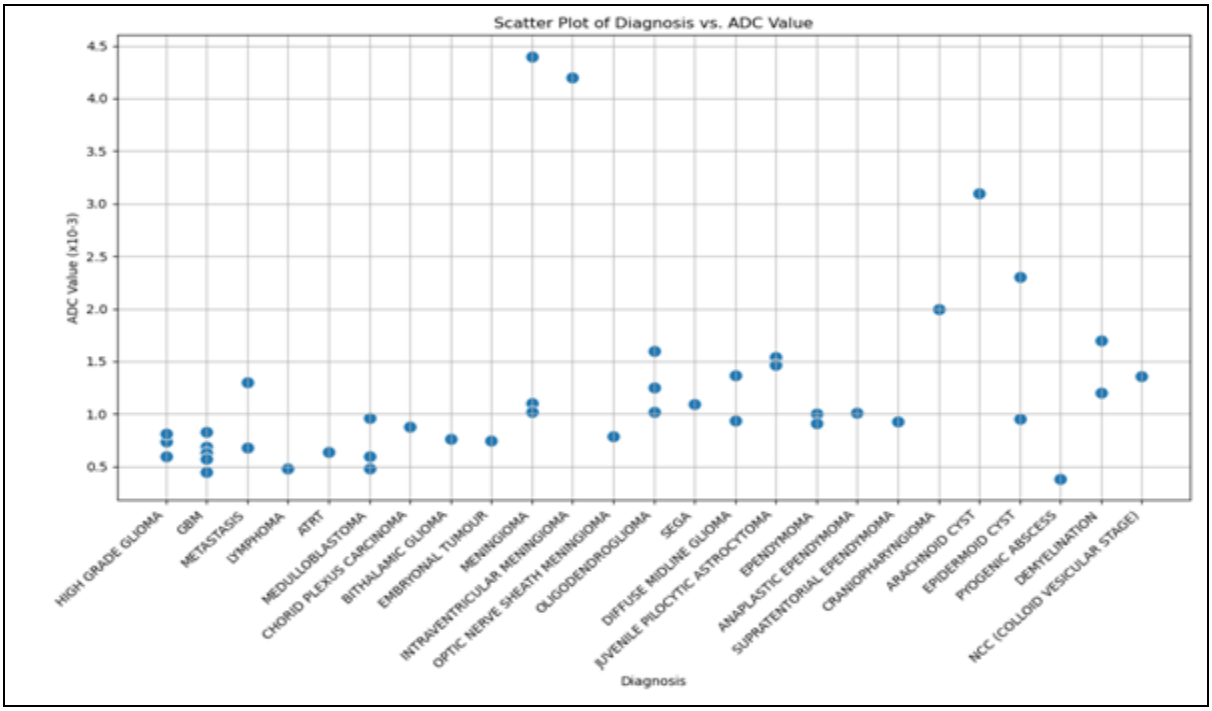

FIG. 1: THE SCATTER PLOT BETWEEN DIAGNOSIS AND ADC

The scatter plot titled "Scatter Plot of Diagnosis vs. ADC Value" illustrates the relationship between different medical diagnoses and their corresponding Apparent Diffusion Coefficient

(ADC) values. Each point on the plot represents an individual diagnosis, with the ADC value on the y-axis (ranging from 0 to 4.5 x 10^-3 mm²/s) and the specific diagnosis on the x-axis. The plot reveals a wide range of ADC values for various diagnoses, indicating the heterogeneity of diffusion characteristics among different types of tumors and conditions. Diagnoses such as "HIGH GRADE GLIOMA" and "GBM" cluster at lower ADC values around 0.5 to 1.0, suggesting their high aggressive nature. In contrast, conditions like "Meningioma" and "Oligodendroglioma" exhibit higher ADC values, indicating their less aggressive nature. This spread in ADC values across diagnoses can help in differentiating between various types of brain lesions based on their aggressive nature.

TABLE 2: DISTRIBUTION OF SUPRATENTORIAL AND INFRATENTORIAL

WHO Grade	Supratentorial		Infratentorial	
	Count	Percentage	Count	Percentage
I	2	6.06	1	10.0
II	7	21.21	2	20.0
III	4	12.12	1	10.0
IV	15	45.46	4	40.0
Non-Neoplastic	5	15.15	2	20.0

Table 2 presents the distribution of supratentorial and infratentorial lesions categorized by WHO grade in a sample. For supratentorial lesions, the majority are Grade IV (45.46%), followed by Grade II (21.21%), Grade III (12.12%), and Grade I (6.06%), with non-neoplastic lesions accounting for 15.15%. In contrast, for infratentorial lesions, the distribution shows a higher proportion of Grade IV (40.0%), followed by Grade II (20.0%), and equal proportions of Grade I and Grade III (10.0% each), with non-neoplastic lesions making up 20.0%. This indicates that higher-grade lesions (Grade IV) are more common in both supratentorial and infratentorial regions, while non-neoplastic lesions are relatively less common.

TABLE 3: SUMMARY OF DIAGNOSIS AND CONTRAST ENHANCEMENT

WHO Grade	No. of Patients	Contrast Enhancement				
		ABS NT	RIG	Miniml	Hetero Geneous	Homo Geneous
I	4	1	2	-	-	1
II	10	1	1	-	2	5
III	5	2	-	-	3	-
IV	20	2	7	5	3	2
Non-Neoplastic	7	3	4	-	-	-

Table 3 indicates that higher-grade lesions (Grades III and IV) are more likely to exhibit heterogeneous enhancement, while lower-grade lesions (Grades I and II) and non-neoplastic lesions show a mix of contrast enhancement patterns. Specifically, Grade II lesions frequently demonstrate homogeneous enhancement, whereas Grade IV lesions display a varied enhancement profile, including rigid, minimal, and heterogeneous patterns. Non-neoplastic lesions predominantly show either no enhancement or rigid enhancement.

TABLE 4: SUMMARY OF DIAGNOSIS AND DIFFUSION RESTRICTIONS

WHO Grade	Number of patients	Diffusion Restrictions		
		Partial	Complete	No
I	4	-	-	4
II	8	2	-	6
III	5	3	-	2
IV	18	10	6	2
Non-Neoplastic	7	-	2	5

Table 4 summarizes the diffusion restrictions in various WHO grades of lesions. For Grade I lesions, all 4 patients show no diffusion restriction. In Grade II lesions, out of 8 patients, 2 exhibit partial diffusion restriction, while 6 show no restriction. Grade III lesions include 5 patients,

with 3 showing partial and 2 showing no diffusion restriction. Grade IV lesions, involving 18 patients, display significant diffusion restrictions: 10 with partial and 6 with complete restrictions, while only 2 show no restriction. Among the 7 non-neoplastic lesions, 2 have complete diffusion restrictions and 5 have none. This indicates that higher-grade lesions, particularly Grade IV, are more likely to exhibit both partial and complete diffusion restrictions, whereas lower-grade and non-neoplastic lesions tend to have no diffusion restrictions.

TABLE 5: SUMMARY OF DIAGNOSIS AND PERILESIONAL EDEMA

WHO Grade	Number of patients	Perilesional Edema	
		Yes	No
I	4	-	4
II	9	4	5
III	5	4	1
IV	18	15	3
Non-Neoplastic	7	2	5

Table 5 summarizes the presence of perilesional edema across different WHO grades of lesions. For Grade I lesions, all 4 patients show no perilesional edema. In Grade II lesions, 9 patients are split between 4 with edema and 5 without. Grade III lesions show 4 out of 5 patients with edema, while only 1 patient does not have it. Among the 18 patients with Grade IV lesions, 15 exhibit perilesional edema and 3 do not. In the non-neoplastic category, 2 out of 7 patients have perilesional edema, and 5 do not. This data indicates that higher-grade lesions, particularly Grades III and IV, are more frequently associated with perilesional edema, while lower-grade lesions and non-neoplastic conditions are less likely to exhibit this feature.

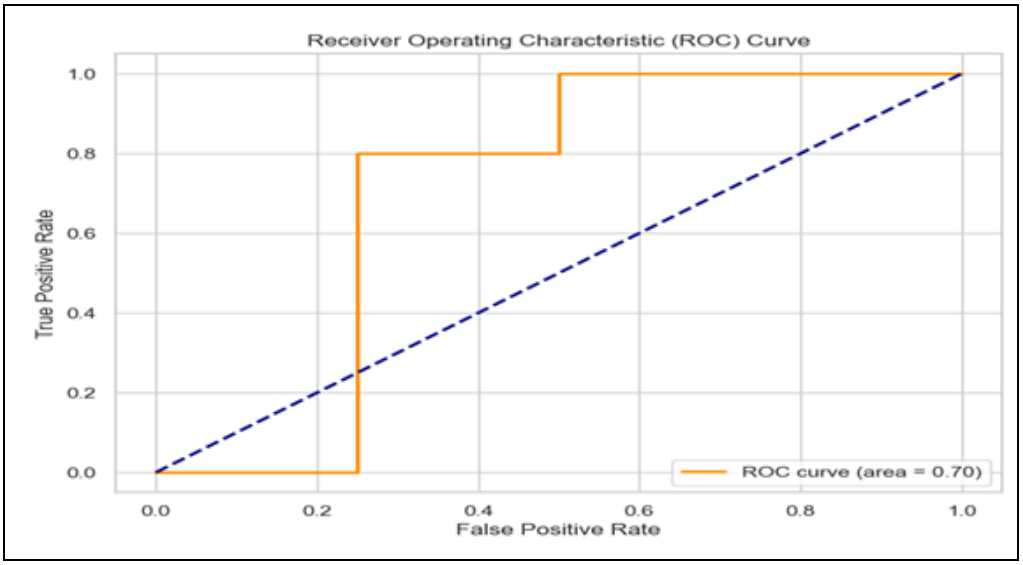

FIG. 2: RECEIVER OPERATING CHARACTERISTIC (ROC) CURVE

Fig. 2 illustrates the Receiver Operating Characteristic (ROC) curve displayed in the graph and evaluates the diagnostic performance of Diffusion Weighted Imaging (DWI) in identifying intracranial lesions. The curve plots the true positive rate (sensitivity) against the false positive rate (1-specificity) at various threshold settings. The area under the curve (AUC) is 0.70, indicating that DWI has a fair level of accuracy in distinguishing between intracranial lesions and normal tissue. An AUC of 0.70 suggests that there is a 70% chance that the DWI will correctly differentiate between a randomly chosen lesion and a non-lesion case, reflecting moderate diagnostic ability. This supports the role of DWI as a useful tool in the evaluation of intracranial lesions, though it also highlights the need for complementary diagnostic methods to improve overall accuracy.

DISCUSSION: Diffusion Weighted Imaging (DWI) is essential in the assessment of intracranial lesions, providing unique insights into cellular

environments and the movement of water molecules within the brain. By measuring the random Brownian motion of water molecules, DWI offers crucial information on the density and integrity of cellular structures.

This imaging technique has revolutionized the approach to diagnosing and characterizing various intracranial pathologies, enhancing the ability to distinguish between different types of brain lesions based on their diffusion properties [1, 2].

In the context of acute stroke management, DWI is invaluable. It enables the rapid identification of ischemic regions by detecting early cytotoxic edema, which is not visible on conventional MRI or CT scans. The high sensitivity of DWI to acute infarctions allows clinicians to initiate timely interventions, significantly improving patient outcomes.

The characteristic hyperintensity on DWI, combined with reduced apparent diffusion coefficient (ADC) values, marks the infarcted areas, facilitating prompt and accurate diagnosis. Like our study Rastogi *et al.* 2015 and Merino *et. al.* 2010 reported that DWI is highly sensitive for diagnosis and imaging of acute stroke and their managements among the patients [8].

Beyond stroke, DWI is instrumental in differentiating between various brain tumor types. Malignant tumors often exhibit restricted diffusion due to high cellularity and a dense extracellular matrix, resulting in hyperintense signals on DWI and low ADC values. Conversely, benign lesions, such as low-grade gliomas, typically show less restricted diffusion, presenting with intermediate or low signal intensity on DWI and higher ADC values. This differentiation is crucial for planning appropriate treatment strategies and predicting patient prognosis [9].

DWI also plays a vital role in diagnosing and managing infections and inflammatory conditions of the brain. For instance, brain abscesses and other pyogenic infections display markedly restricted diffusion due to the thick, viscous pus and dense cellular infiltrates within the lesions. This results in distinctive hyperintense DWI signals and low ADC values, distinguishing these conditions from non-infectious inflammatory processes or necrotic tumors, which usually demonstrate different diffusion characteristics [10]. In the assessment of demyelinating conditions such as multiple sclerosis (MS), DWI offers extra diagnostic insights. Acute demyelinating lesions frequently exhibit modified diffusion characteristics, which can assist in distinguishing them from chronic plaques.

The capability to detect these subtle variations aids in the early identification of MS and in tracking disease progression and therapeutic response, thereby enhancing the management of the condition. DWI is also applied in the assessment of brain metastases.

Metastatic lesions often show variable diffusion characteristics depending on their origin and histological features. By analyzing the diffusion properties of these lesions, DWI helps differentiate metastatic tumors from primary brain tumors and other intracranial abnormalities.

This differentiation is crucial for determining the appropriate therapeutic approach and assessing prognosis. The study by Toh *et al.* (2011) explored the diffusion properties of cystic brain lesions, comparing abscesses, glioblastomas and metastases.

Their findings revealed that abscess cavities displayed hyperintense Diffusion Weighted Imaging (DWI) signals with low apparent diffusion coefficient (ADC), low mean diffusivity (MD), and high fractional anisotropy (FA). Conversely, most glioblastoma and metastatic cysts showed hypo intensity on DWI, high ADC, high MD, and low FA [11].

Our study identified Glioblastoma Multiforme (GBM) as the most common diagnosis, making up 11.36% of the cases with 5 cases showing partial restriction on DWI with low ADC values ranging from (0.45 to 0.83 x $10^{-3)}$ and high mean diffusivity, low fractional anisotropy, conversely one case of brain abscess showed complete diffusion restriction with low ADC value ($0.45x10^{-3}$), low mean diffusivity and high FA. Thus, differentiating GBM from ABSCESS with DWI with 96% sensitivity and specificity overcoming the challenges faced by TOH *et al.*

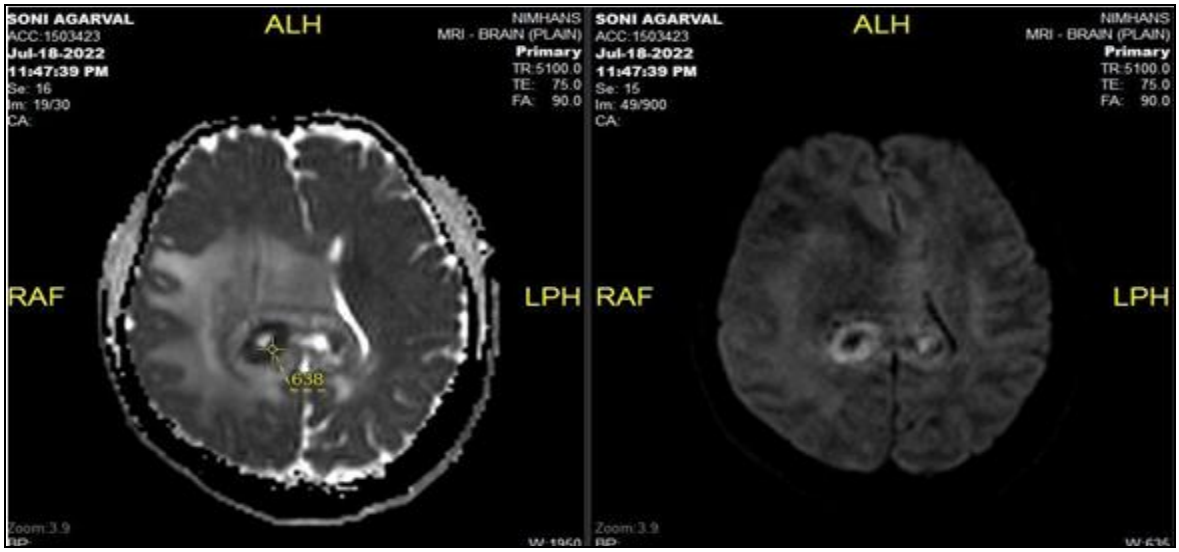

FIG. 3: ADC AND DWI IMAGES IN A CASE OF GLIOBLASTOMA SHOWING PARTIAL DIFFUSION RESTRICTION WITH LOW ADC VALUE (0.63X10-3) REFLECTING THEIR HIGH CELLULAR NATURE. THE TUMOR IS CROSSING MIDLINE WITH VASOGENIC EDEMA.

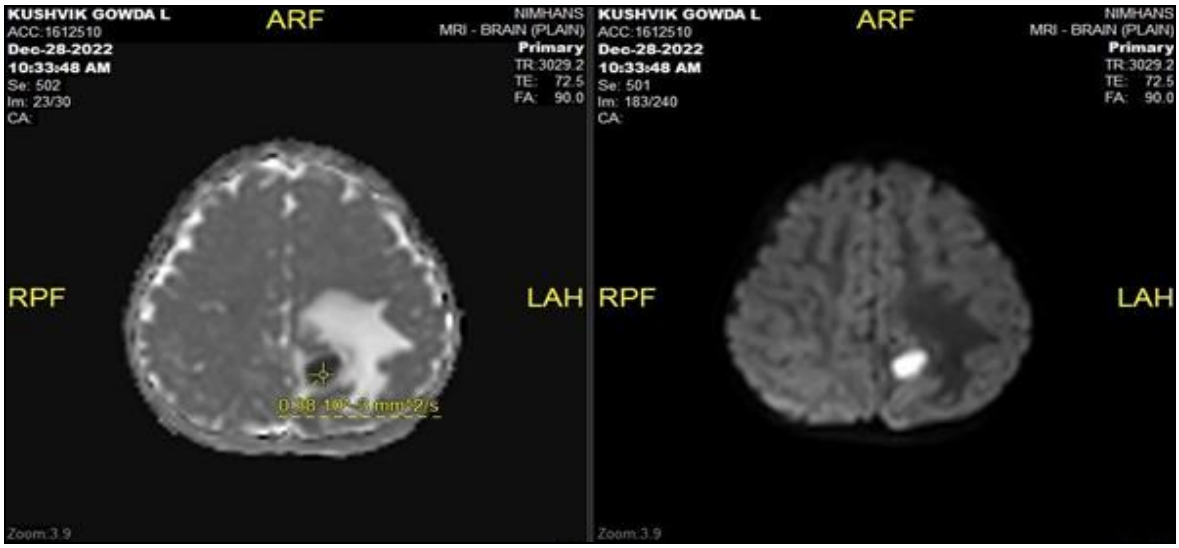

FIG. 4: ADC AND DWI IMAGES IN A CASE OF PYOGENIC BRAIN ABSCESS SHOWING TRUE DIFFUSION RESTRICTION WITH LOW SIGNAL ON ADC. THERE IS A SIGNIFICANT PERI LESIONAL EDEMA.

Sathyakumar K *et al.* (2021) analyzed MRI data from 82 children with infratentorial tumors, categorized into low-grade (WHO grades I and II) and high-grade (WHO grades III and IV). They found that diffusion restriction and low apparent diffusion coefficient (ADC) values were characteristic of high-grade tumors ($p < 0.001$). Mean ADC values were 1.567 × 10^-3 mm²/s for low-grade and 0.661 × 10^-3 mm²/s for high-grade tumors. Using a cut-off ADC value of 0.9 × 10^-3 mm²/s, differentiation between grades showed high sensitivity (87%), specificity (100%), and predictive values (positive: 100%, negative: 81.8%). Significant differences were observed in mean ADC values among individual tumor types ($p < 0.05$), except between medulloblastoma and ATRT [12]. Our study also analysed ADC values across various brain tumors, finding that high-grade tumors (Grade IV gliomas, medulloblastoma, and ATRTs) exhibited lower ADC values, indicating their dense, aggressive nature. Low-grade tumors like meningiomas had higher ADC values due to their fluid-filled structure. Mean ADC values were 1.711 x 10^-3 mm²/s for low-grade and 0.74 x 10^-3 mm²/s for high-grade tumors, with a statistically significant difference ($P < 0.0001$). Like Sathyakumar K *et al.*, we faced challenges in differentiating ATRT from medulloblastoma due to their close mean ADC values.

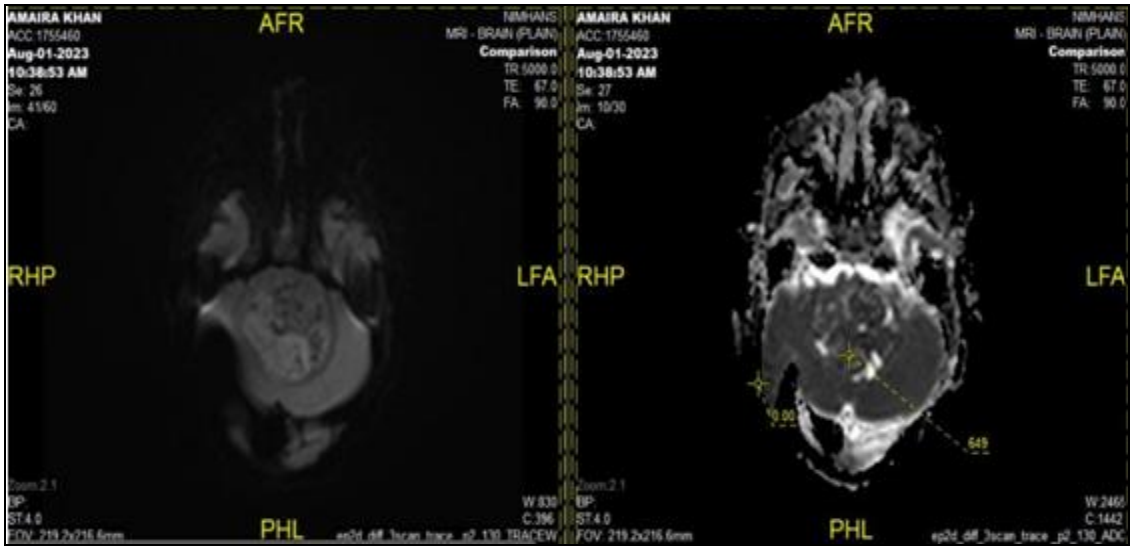

FIG. 5: DWI AND ADC IMAGES IN A CASE OF 1 YEAR OLD GIRL WITH ATRT SHOWING DIFFUSION RESTRICTION AND LOW ADC VALUE (0.64X10-3). ATRT MIMICS MEDULLOBLASTOMA DUE TO ITS CENTRAL LOCATION IN *POSTERIOR FOSSA* AND ITS HIGHLY CELLULAR AND HETEROGENEOUS NATURE

Ningappa *et al.* 2016 study emphasizes the utility of apparent diffusion coefficient (ADC) values in differentiating various types of brain mass lesions and grading brain tumours. They found positive correlation in the comparison of mean ADC values for high-grade gliomas (1.19 × 10−3 mm2/s ± 0.2) and metastasis (0.833 × 10−3 mm2/s ± 0.2), low-grade gliomas (1.34 × 10−3 mm2/s ± 0.2), and medulloblastomas (0.68 × 10−3 mm²/s ± 0.075), as well as for epidermoid cyst, abscess and necrotic areas in malignant tumors [13]. In comparison our study found significant positive correlation between the mean ADC values in differentiating between high grade tumours like Medulloblastomas (0.68×10−3 mm²/s ± 0.043) from low grade tumors like Ependymomas (1.01 × 10−3 mm²/s ± 0.067), which is important for differentiation of both these tumors as they both are infratentorial in location. Thus, our study complements the field of pediatric neurology by differentiating these commonly occurring posterior fossa tumours in children.

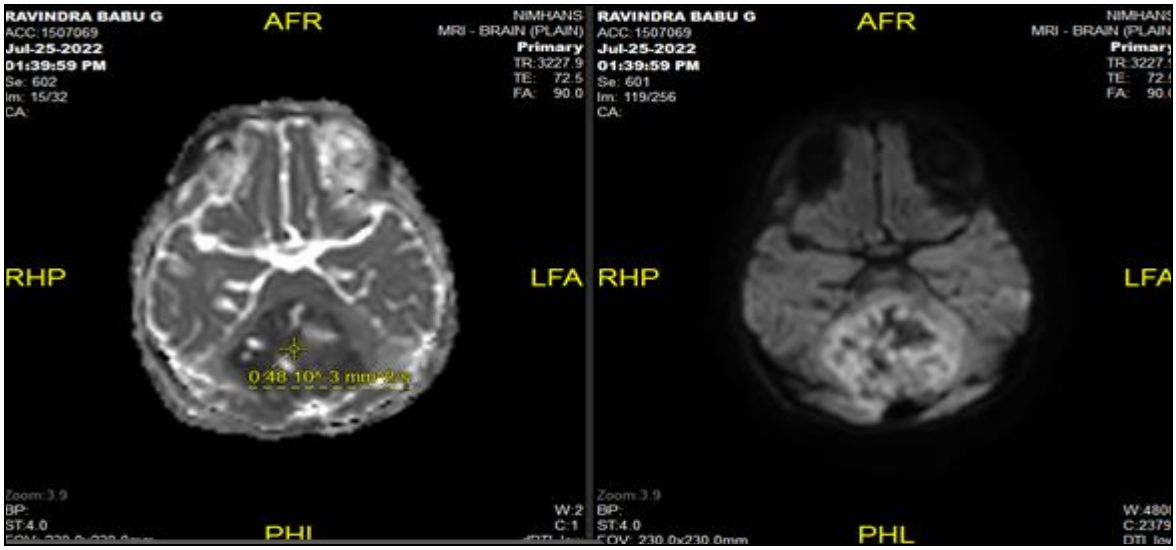

FIG. 6: DWI AND ADC MR BRAIN IMAGES IN A CASE OF MEDULLOBLASTOMA SHOWING COMPLETE DIFFUSION RESTRICTION WITH SIGNIFICANTLY LOW ADC VALUES THUS DIFFERENTIATING IT FROM LOW GRADE EPENDYMOMA

Our study delves into the mean ADC values across different brain tumor types, highlighting the heterogeneity in tumor characteristics. High-grade tumors such as GBM, Atypical Teratoid/Rhabdoid

Tumor (ATRT), and Diffuse Midline Glioma exhibit low ADC values, indicating their dense cellular structure and aggressive nature. Conversely, lower-grade tumors like Ependymoma Grade II and Juvenile Pilocytic Astrocytoma Grade I show higher ADC values, correlating with their less aggressive and less cellular architecture. Non-neoplastic lesions, such as Arachnoid Cysts and Epidermoid Cysts, demonstrate high ADC values, reflecting their cystic and fluid-filled composition.

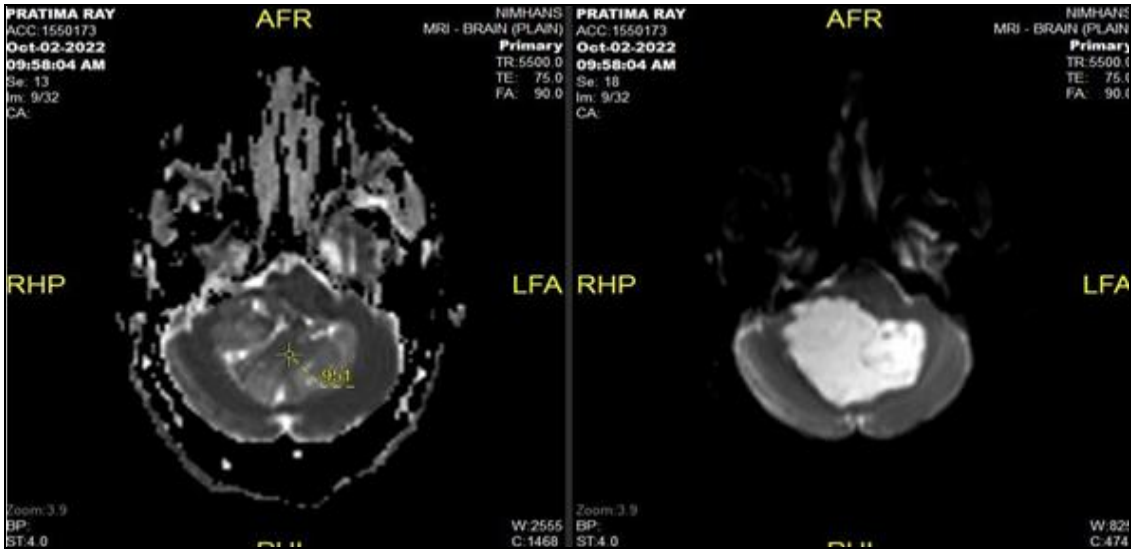

FIG. 7: ADC AND DWI IMAGES IN A CASE OF EPIDERMOID CYST SHOWING TYPICAL T2 SHINE THROUGH EFFECT

The significance of our study lies in providing a comprehensive understanding of the ADC value ranges across different brain lesions, which aids in distinguishing between various types of tumors and non-neoplastic lesions. By highlighting the variable characteristics of tumor types, our study emphasizes the importance of ADC values in neuro-oncological diagnosis and management. The variability in ADC values within tumor types, such as the high range seen in meningiomas, suggests differing internal compositions or stages of development, adding complexity to tumor evaluation

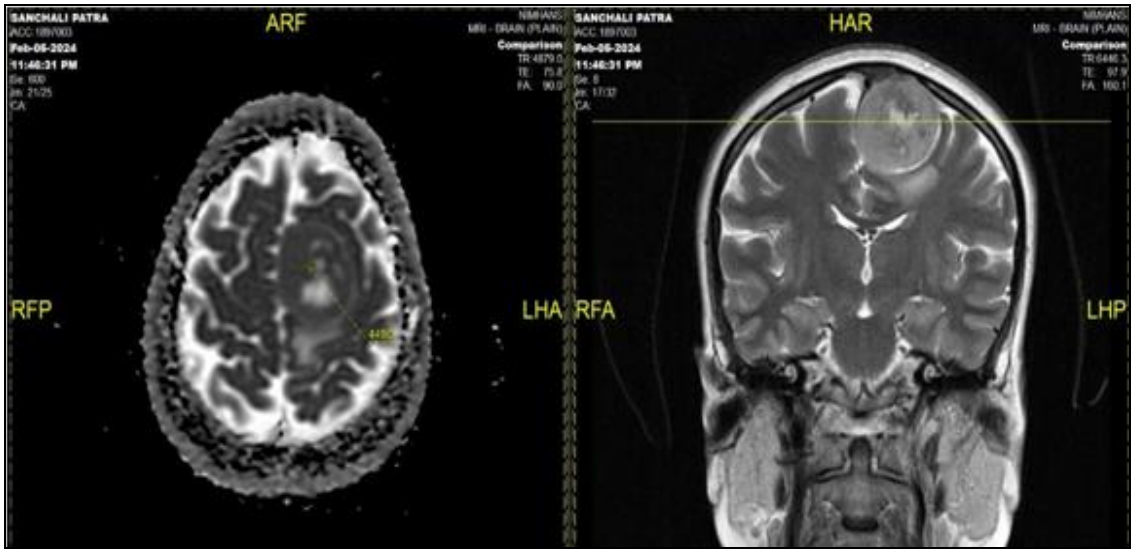

FIG. 8: ADC IMAGE IN A CASE OF MENINGIOMA SHOWING HIGH ADC VALUE SIGNIFYING ITS INCREASED FLUID CONTENT WITHIN THESE LESIONS. T2W IMAGE SHOWING TYPICAL DURAL TAIL SIGN

KY Chan *et al.* (2021) emphasized the value of contrast enhancement patterns in various intracranial lesions such as pyogenic brain abscesses, tumors (including GBM, metastasis, and

CNS lymphoma), and demyelinating conditions like multiple sclerosis. They discussed how these patterns on post-contrast MRI can differentiate these conditions.Our study, on the other hand, focuses on the enhancement patterns of various brain tumors and lesions, providing insights into their aggressiveness and vascular characteristics. We observed minimal contrast enhancement in Grade I tumors, correlating with their less aggressive nature. Grade II tumors exhibited a mix of enhancement patterns, indicating diverse pathology. Grade III tumors predominantly showed heterogeneous enhancement, suggesting more aggressive behavior and irregular blood supply. Grade IV tumors displayed the widest variety of enhancement patterns, including significant ring enhancement, underscoring their aggressive and diverse nature. Non-neoplastic conditions like cerebral abscesses showed complete ring enhancement, whereas tumefactive demyelination showed incomplete ring enhancement, aiding in differentiation based on enhancement patterns. Thus, our study complements the study by KY Chan by focusing on contrast enhancement patterns in brain tumors, providing a deeper understanding of tumor aggressiveness and vascular characteristics.

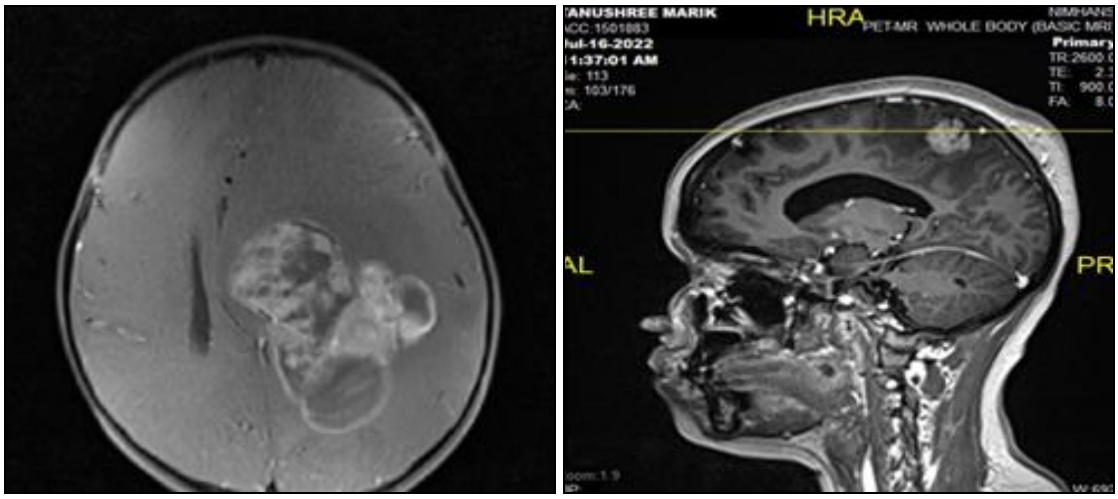

FIG. 9: POST CONTRAST T1 WEIGHTED IMAGES IN THE CASE OF CHOROID PLEXUS CARCINOMA SHOWING HETEROGENEOUS ENHANCEMENT AND IN CASE OF LYMPHOMA SHOWING MORE HOMOGENEOUS ENHANCEMENT

In summary, Jaroch K *et. al.* 2021 study emphasizes the potential of ADC values to predict the degree of malignancy in astrocytic tumors, despite some overlap between grades [14]. *Daftari et al.'s* 2022 study highlights the efficacy of diffusion-weighted imaging (DWI) in detecting ischemic lesions in acute stroke patients. The study also noted that lesion volume tends to increase over time, likely due to the infarction of surrounding tissue or vasogenic edema. Furthermore, lesion size on early DWI scans correlated with clinical outcomes, suggesting that early lesion volume could serve as a prognostic indicator for stroke recovery [15]. In contrast, our study analyses ADC values across various brain tumors and lesions, using these values to infer the physical properties and aggressiveness of the tumors. We found that high-grade tumors such as Grade IV gliomas and ATRTs exhibited lower ADC values, indicative of their dense and aggressive nature, while benign and non-neoplastic conditions like arachnoid cysts showed higher ADC values due to their fluid-filled structure. Our use of interquartile range (IQR) to measure variability in ADC values highlighted the heterogeneity within certain diagnoses, with broader IQRs suggesting more diverse tumor characteristics. The significance of our study lies in its detailed examination of ADC values to differentiate between various intracranial lesions, providing crucial diagnostic insights. Additionally, understanding the variability within ADC values for specific diagnoses can inform future research and improve diagnostic accuracy.

We observed that low-grade tumors typically exhibited no diffusion restriction, reflecting their less aggressive nature and higher extracellular space allowing for free diffusion of water

molecules. However, as tumor grade increased, we observed varying degrees of diffusion restriction, with Grade IV tumors, such as glioblastomas, showing the highest severity. Mong *et al.* 2012 findings align with the known biology of brain tumors, where increased cellularity and aggressiveness correspond to restricted diffusion on DWI [16]. By identifying specific diffusion characteristics associated with different tumor grades and types, our study contributes to improving the accuracy of tumor diagnosis and prognosis. Understanding the nuances of diffusion restriction in various intracranial pathologies is crucial for guiding treatment decisions and predicting patient outcomes. Overall, our findings add to the growing body of literature on the utility of DWI in neuro-oncology and underscore its importance in clinical practice for evaluating brain tumors and lesions.

In contrast, high-grade tumors (WHO Grade III and IV) exhibited a higher incidence of perilesional edema, indicative of their aggressive behavior and potential to significantly disrupt surrounding brain tissue. Non-neoplastic conditions also showed perilesional edema, albeit to a lesser extent, reflecting underlying inflammatory or pathological processes. The Receiver Operating Characteristic (ROC) curve analysis in our study provides insights into the predictive ability of ADC values in distinguishing between high-grade and low-grade brain tumors. By transforming the multi-class classification problem into a binary one, we assessed the discriminative ability of ADC values in categorizing tumors based on their aggressiveness. An Area under the Curve (AUC) of 0.70 indicates moderate discriminative ability, suggesting that ADC values can moderately differentiate between high-grade and low-grade tumors. Overall, the significance of our study lies in its comprehensive characterization of brain tumors based on ADC values and perilesional edema patterns. By elucidating these features across different tumor grades and types, our study contributes to a better understanding of tumor behavior and provides valuable insights for clinical decision-making. Incorporating ADC measurements and perilesional edema assessment into routine MRI evaluations can enhance diagnostic accuracy and prognostic prediction in patients with brain lesions. Similar to our study Momeni *et al.* 2021 reported that the ADC values from the MRI DWIs in the tumor core and edema could serve as a suitable approach for examining the distinctions between low- and high-grade glioma tumors [17].

CONCLUSION: In conclusion, this study highlights the critical role of Diffusion Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) values in the diagnosis and characterization of intracranial lesions. Our findings demonstrate that high-grade tumors exhibit significantly lower ADC values and are more likely to be associated with perilesional edema and diffusion restrictions, underscoring their aggressive nature. The ROC curve analysis confirms the moderate accuracy of DWI in distinguishing between different grades of brain tumors, emphasizing its diagnostic utility. By providing a comprehensive analysis of ADC value ranges across various brain lesions, this study supports the incorporation of DWI and ADC measurements into routine MRI evaluations, enhancing diagnostic precision and aiding in the formulation of tailored treatment strategies. Further research is necessary to refine these imaging techniques and improve their overall diagnostic accuracy for better clinical outcomes in neuro-oncological practice.

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