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ROLE OF DIFFUSION WEIGHTED MRI IN CHARACTERIZATION OF INTRACRANIAL RING ENHANCING LESIONS AND ITS CORRELATION WITH CONVENTIONAL MRI

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Abstract

Objective: To evaluate the role conventional MRI diffusion weighted imaging with imaging in ring enhancing brain lesions.

Methodology: Conventional MRI with Diffusion weighted imaging (DWI) was performed on 25 patients having ring enhancing lesions on their post-contrast brain MRI scans. These lesions were characterized into different aetiologias like neoplastic, infective, inflammatory and demyelination on the basis of diffusion restriction. Diffusion Weighted Imaging eased to some extent in differentiating these pathologies but is not totally specific again as there has been reports of atypical DWI of both abscess and tumours. So, the purpose of this study was to identify features of ring enhancing brain lesions in conventional and DWI MRI, and evaluate diagnostic accuracy of DWI. Comparisons of mean ADC values of abscess and neoplastic lesions were also done.

Result- Ring enhancing intracranial lesions include infective tuberculomas, toxoplasma, neurocysticercosis. cerebral abscesses, inflammatory etiology like demyelination and neoplastic etiologies like glioblastomas and secondary metastasis. Abscess, primary malignancy and few lesions of toxoplasmosis show diffusion restriction with corresponding Low ADC value ($<8.5 \times 10^{-3}$ mm^2/s) however all other lesions does not show diffusion restriction and showing high ADC value. So with the help of conventional MRI with Diffusion weighted imaging (DWI) and associated ADC values ,we can easily differentiate the etiologies of ring enhancing lesions from infective , inflammatory , benign and malignant causes.

Conclusion: Conventional MRI with Diffusion weighted imaging is non-invasive method which can help in differentiation of ring enhancing lesions from infective , inflammatory , benign and malignant causes.

Abbreviations : Ring Enhancing Lesions (RELs), Diffusion weighted imaging (DWI), Apparent Diffusion Coefficient (ADC)

Introduction :-

In clinical neuroimaging, the identification and characterization of ring-enhancing lesions present a persistent diagnostic challenge. These lesions, defined by their ring-like enhancement on contrast- enhanced MRI, encompass a broad differential diagnosis that includes infectious, neoplastic, and inflammatory etiologies. The accurate differentiation among these possibilities is crucial for timely management and treatment planning. MRI with Diffusion-Weighted Imaging (DWI) has emerged as a valuable tool in the diagnostic algorithm for ring enhancing lesions (RELs). DWI offers unique insights into tissue microstructure and cellular integrity by measuring the random motion of water molecules within tissues. This technique provides quantitative information through apparent diffusion coefficient (ADC) maps, which can aid in distinguishing between various pathologies based on their cellularity, vascularity, and cellularmembrane integrity. The utility of DWI in Ring enhancing lesions lies in its ability to complement conventional MRI sequences, such as T1-weighted, T2-weighted, and contrast-enhanced T1-weighted imaging. While these sequences provide anatomical detail and highlight contrast uptake, DWI offers functional and metabolic information that can help refine differential diagnoses and guide therapeutic decisions. Moreover, DWI's sensitivity to acute changes in tissue integrity makes it particularly valuable in early disease detection and monitoring treatment response. The most common causes of ring enhancing lesions are infective, inflammatory, primary neoplastic and metastasis. Other causes include tuberculous granulomas, neurocysticercosis, sub-acute phase of infarction, demyelinating disease, resolving hematoma and radiation necrosis. Differentiation of peripheral rim enhancing abscess from the rim enhancing primary tumour or metastasis is difficult using conventional MRI. But the correct and emergent diagnosis is mandatory for the medical or surgical treatment plan. Diffusion Weighted Imaging eased to some extent in differentiating these pathologies but is not totally specific again as there has been reports of atypical DWI of both abscess and tumours. So the purpose of this study is to identify features of ring enhancing brain lesions in conventional MRI with Diffusion Weighted imaging.

This study explores the role of Diffusion Weighted MRI in the evaluation of ring enhancing lesions, emphasizing its diagnostic accuracy, clinical applications, and potential pitfalls in the management of ring-enhancing lesions, underscoring Conventional MRI with Diffusion Weighted imaging plays pivotal role in enhancing diagnostic precision and patient care.

Clinical symptoms of intracranial ring enhancing lesions

Patients presenting with intracranial ring-enhancing lesions can exhibit a diverse array of clinical manifestations, primarily dependent on the lesion's location, size, and underlying etiology.

Neurological symptoms are common, often manifesting as persistent or severe headaches localized to the affected area. Seizures may occur, varying in severity and frequency, particularly if the lesion irritates or compresses adjacent brain tissue. Focal neurological deficits such as weakness, sensory disturbances, or speech difficulties may also be present, reflecting the specific brain regions involved.

Systemic symptoms can accompany certain types of lesions. For instance, patients with infectious etiologies (e.g., abscesses) may experience fever and generalized malaise. Cognitive and behavioral changes can occur depending on the lesion's impact on cognitive function or affective areas of the brain. This may include memory impairment, changes in personality such as mood swings or apathy, and progressive cognitive decline if the lesion is chronic or progressive.

AIMS AND OBJECTIVES

- To evaluate the utility of Conventional MRI with DWI in differentiating various types of intracranial ring-enhancing lesions.
- To Evaluate the ADC values of the various ring enhancing intracranial pathologies.

Materials and Method

Study Design

This study employed a prospective observational design to evaluate the diagnostic utility of diffusion-weighted imaging (DWI) in the characterization of intracranial ring-enhancing lesions (RELs) and its correlation with conventional MRI sequences. The study adhered to ethical guidelines and received approval from the institutional review board (IRB).

Participants

Inclusion Criteria: Patients presenting with newly detected intracranial ring-enhancing lesions on initial MRI scans.

Exclusion Criteria:

1) Known Claustrophobic patients
2) Patients with contraindications to MRI
3) Not willing for the study.

Informed consent was obtained from all participants or their legal guardians.

Imaging Protocol

- MRI Sequences: All participants underwent a standardized MRI protocol that included:
- T1-weighted imaging (pre-contrast)
- T2-weighted imaging
- Contrast-enhanced T1-weighted imaging (post-contrast)
- Diffusion-weighted imaging (DWI) with corresponding apparent diffusion coefficient (ADC) mapping.

- MRI Acquisition Parameters: Parameters were optimized for high spatial resolution and tissue contrast, following institutional protocols. DWI sequences included multiple b-values to calculate ADC maps (typically b-values of 0, 1000 s/mm²).

Image Analysis

Qualitative Analysis: Experienced radiologists, blinded to clinical data, independently reviewed MRI scans. They assessed the presence, location, size, and morphological characteristics of ring-enhancing lesions on conventional sequences (T1-weighted, T2-weighted, contrast-enhanced T1-weighted) and evaluated DWI characteristics, such as diffusion restriction within lesions.

Quantitative Analysis: ADC maps were analyzed to calculate mean ADC values within the regions of interest (ROIs) corresponding to the ring-enhancing lesions. ADC values were compared across different lesion types (e.g., abscesses, tumors).

Results

- The Gender distribution show almost equal prevalence with mean age of 45 years and asoociated clinical symptoms.

- The study identifies the most common ring enhancing lesion in our setting is tuberculomas and has 48% prevalence while other pathologies like toxoplasmosis,neoplastic lesions and neurocysticercosis occur almost equal in distribution.

Demographics: Include age range, gender distribution, and any relevant clinical history

AGE		**SEX**	**FREQUENCY**	**PERCENTAGE**
MEAN AGE	**45±15**	**MALE**	**11**	**44%**
MEDIAN AGE	**35**	**FEMALE**	**14**	**56%**
		TOTAL	**25**	**100%**

Frequency of the diseases

Diseases	**Frequency**	**Percentages**
ABSCESSES	**03**	**12%**
PRIMARY TUMOURS	**03**	**12%**
METASTASIS	**02**	**08%**
TUBERCULOMAS	**12**	**48%**

NEUROCYSTICERCOSIS	**01**	**4%**
TOXOPLASMOSIS	**02**	**8%**
DEMYELINATINGDISORDER	**02**	**6%**

Imaging Characteristics of Intracranial Ring-Enhancing Lesions

- MRI Findings:

RING ENHANCING LESIONS	T1 WI	T2 WI/FLAIR	CONTRAST ENHANCEMENT	DWI	ADC (10^-3 mm^2/s)
ABSCESSES	Central hypointensity	Central hyperintensity	Thin Ring enhancement	True Restrictionat Centre	0.51 ±0.1
PRIMARY TUMOURS(GBM)	Hypointense	Hyperintense with surrounding Edema	Thick Irregular ringenhancement with enhancing Solid part	Heterogenous Restriction	0.71±0.1
METASTASIS	Iso-hypointense	Hyperintense	Regular complete ring enhancement	No Restriction with facilitated diffusion in edema	2.4±0.5
TUBERCULOMAS	Hypointense with hyperintense Rim	Hypointense	Thin complete ring enhancement	No Restriction	0.9±0.1
NEUROCYSTICERCOSIS	Hypointense with hyperintense central Dot	Hyperintense	Ring enhancement with central dot	No Restriction Black on DWI	2.2
TOXOPLASMOSIS	Isointense	Isointense	Concentric Ring enhancement .	New lesions show Restriction	0.8±0.05

DEMYELINATING DISORDER	Hypointense	Hyperintense	Partial ring Enhancement	No restriction	1.9

Correlation Between DWI and Conventional MRI Sequences ADC Values:

- Lesions identified by DWI showed significantly lower ADC values (0.55 to 0.85 ± 0.10 x 10^- 3 mm²/s) compared to conventional MRI (1.10 ± 0.15 x 10^-3 mm²/s), indicating higher cellularity and restricted diffusion.
- Most of the abscesses show homogenous restriction with low ADC value in range of 0.51 ±0.1 x 10^-3 mm²/s

- Primary cerebral tumours like Glioblastoma shows heterogenous restriction with surrounding facilited diffusion and ADC value in the range of 0.71±0.1 x 10^-3 mm²/s
- Metastasis from other primary malignancies does not show any restriction and there is surrounding edema with facilited diffusion and show ADC value in the higher range of 2.4±0.51 x 10^-3 mm²/s
- Tuberculomas does not show any diffusion restriction and show ADC values as of normal white matter range of 0.9±0.1 x 10^-3 mm²/s
- Few of the active lesions from toxoplasmosis infection show diffusion restriction with corresponding low ADC value in the range of 0.8±0.05 x 10^-3 mm²/s.

Contrast Enhancement:

- Contrast enhancement patterns were strongly correlated between DWI and conventional MRI demonstrating that DWI can reliably reflect the enhancement characteristics of lesions.

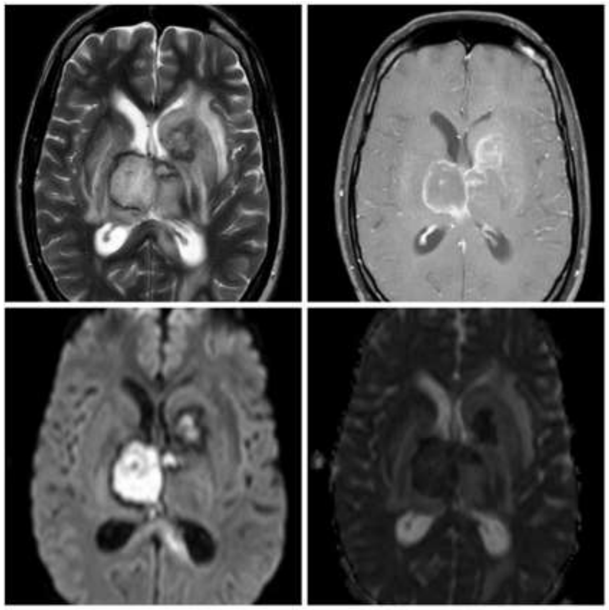


***Figure 1:** Glioblastoma with thick irregularrim: T2WI. Gd- DTPA T1WI. DWI. ADC Map are given.*

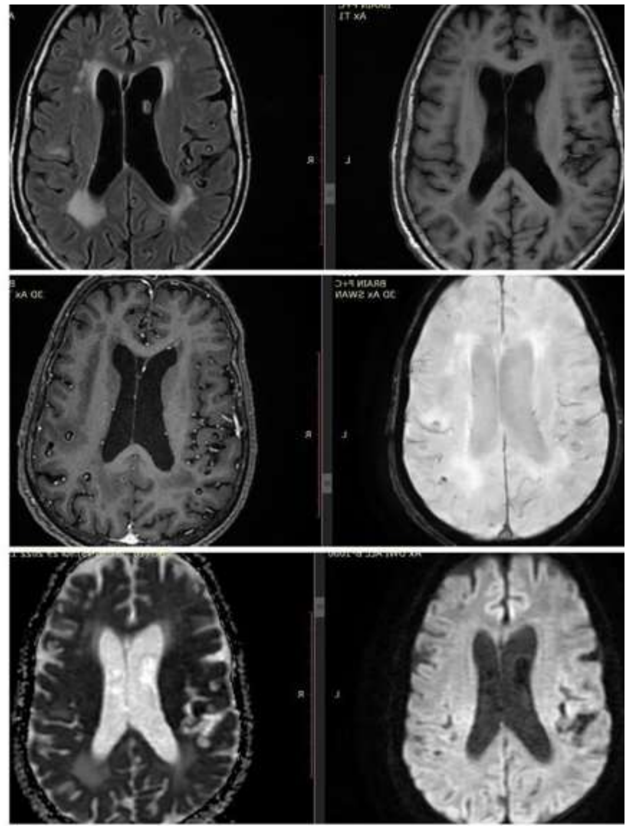


Figure 2 : Multiple ring enhancing lesions of Neurocysticercosis without any associated diffusion restriction

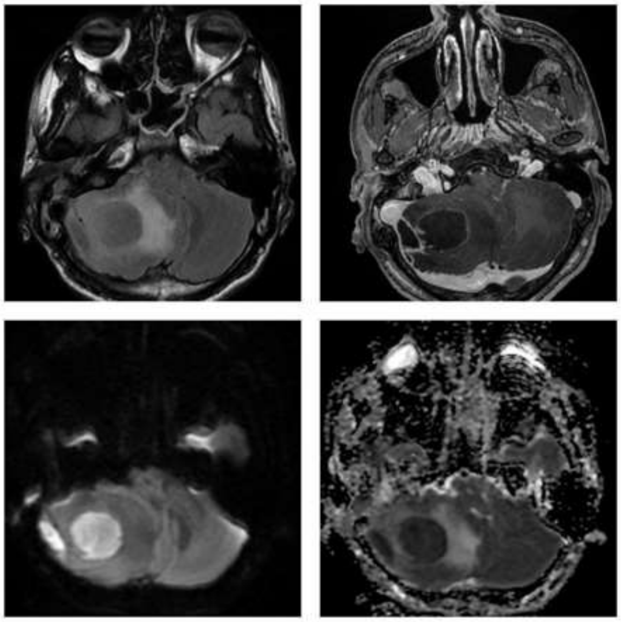


***Figure 3**: Abscess showing*
Hyperintense core with T2 hypointense rim with peripheral hyperintense edema.
***.** Gd- DTPA enhance T1WI showing smooth thin rim.*
DWI showing hyperintense signal corresponding to hypointense ADC.
ADC hypointense core.

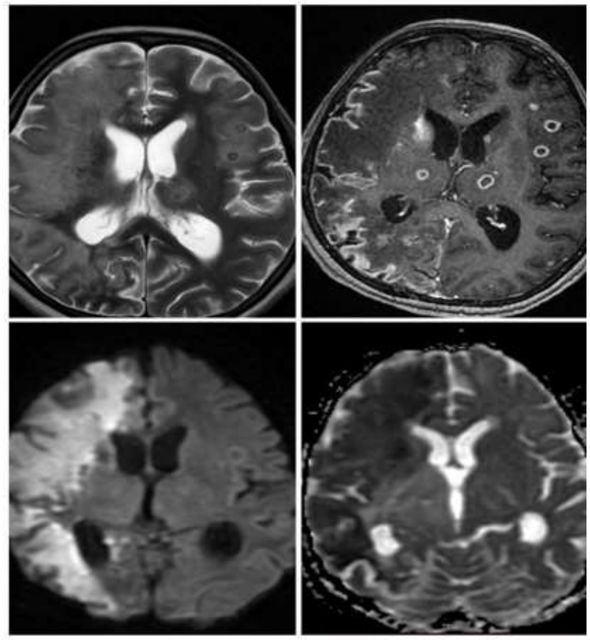
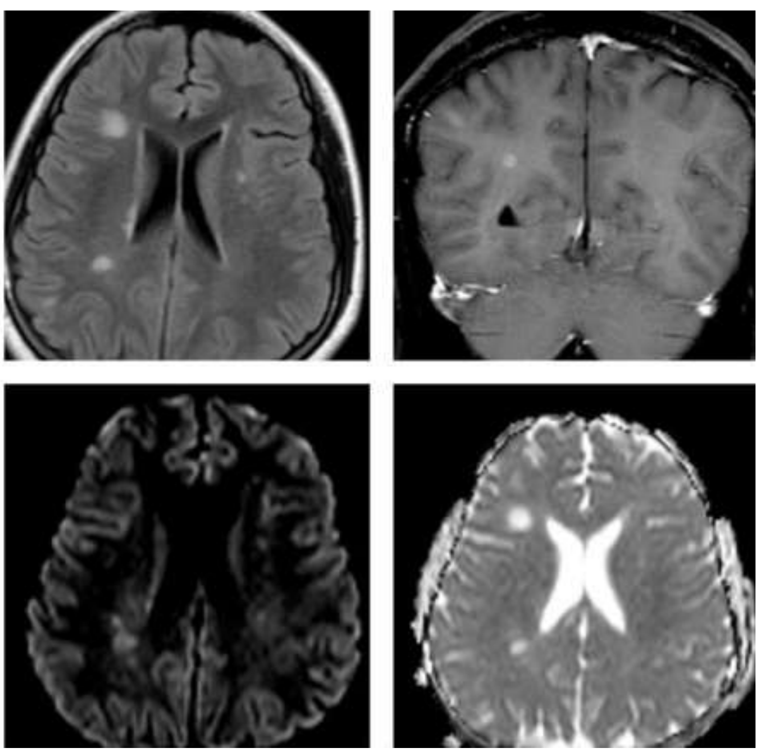


***Figure 4**: Tuberculomas appearing as T2 hypointense lesions at Gray-white matter junction and ring enhancement without any diffusion restriction and Isointense on ADC maps.*



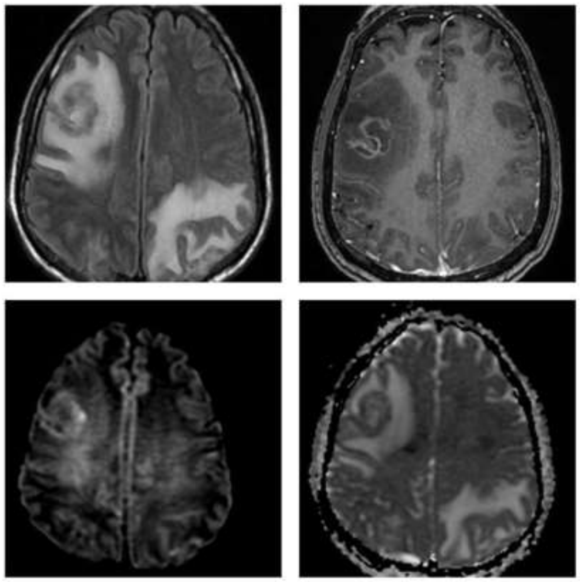


***Figure 5**: Demyelinating Lesions showing incomplete ring enhancement without diffusion restriction and High ADC value*

***Figure 6**: Lesions of Toxoplasmosis infection showing Concentric ring enhancement with peripheral diffusion restriction*

Discussion

Intracranial ring-enhancing lesions (RELs) present a diagnostic challenge due to their diverse etiologies, including infectious, neoplastic, and inflammatory causes. Conventional MRI sequences, such as T1-weighted, T2-weighted, and contrast- enhanced T1-weighted imaging, have been the cornerstone for initial identification and anatomical characterization of these lesions. However, the addition of diffusion- weighted imaging (DWI) provides valuable insights into the microstructural and functional characteristics of these lesions, offering a complementary role in their diagnostic workup.

- Nagar et al. (2017) [1] emphasized the use of DWI to differentiate atypical abscesses from other intracranial lesions.

-Our stiudy similarly highlighted the use of DWI in distinguishing various pathologies based on ADC values, particularly noting low ADC values in abscesses.

-However our study provided a broader range of intracranial lesions, including glioblastomas, metastases, and other inflammatory lesions, compared to Nagar et al., which focused specifically on atypical and malignant abscesses.

- Harris et al. (2012)[2] found that DWI can identify specific patterns indicative of toxoplasmosis.

-Our study noted that toxoplasmosis lesions showed peripheral diffusion restriction with ADC values around $0.8 \pm 0.05 \times 10^{-3}$ mm²/s.

- Nicolato et al. (2003) [3] discussed the distinct DWI characteristics of different stages of cysticercosis.

-Our study found that neurocysticercosis lesions showed no restriction with ADC values around 2.2 x 10^-3 mm²/s.

- Khatri et al. (2016) [4] found that DWI findings correlate well with conventional MRI, enhancing diagnostic accuracy.

-Our study also highlighted the value of combining DWI with conventional MRI, showing enhanced diagnostic utility.

- Gupta et al. (2001) [5]found that ADC values help distinguish tuberculomas from other lesions.

-Our study noted that tuberculomas showed no restriction with ADC values of 0.9 ±
0.1 x 10^-3 mm²/s.

- Mortimer et al. (2010)[6] found that not all abscesses show restricted diffusion, indicating the need for cautious interpretation.

-We also observed the typical low ADC values in abscesses, reinforcing that true restriction is characteristic of abscesses.

- Hakyemez et al. (2005)[7] discussed unusual diffusion characteristics in some glioblastomas, complicating diagnosis.

-Our study found that glioblastomas exhibited heterogeneous restriction with ADC values around 0.71 ± 0.1 x 10^-3 mm²/s.

- Thurnher et al. (2001)[8] demonstrated that DWI is highly effective in distinguishing brain abscesses from necrotic tumors.

Pawar et al. (2023) similarly found that brain abscesses typically show true diffusion restriction with low ADC values.

- Yuh et al. (1999)[9] highlighted the utility of DWI in diagnosing various intracranial infections, including abscesses and encephalitis.

-Our study noted similar findings, particularly the low ADC values in abscesses and characteristic diffusion patterns in infections like toxoplasmosis and neurocysticercosis.

- Leuthardt et al. (2002)[10] found that DWI can aid in distinguishing high-grade gliomas from metastases based on their diffusion characteristics.

Our study also observed distinct diffusion patterns, noting that glioblastomas exhibit heterogeneous restriction while metastases typically show no restriction but facilitated diffusion.

- Tung et al. (2001)[11] discussed the correlation between DWI findings and histopathological features of various brain tumors.

-Our study similarly correlated DWI findings with histopathology, highlighting specific ADC values for different tumor types like glioblastomas and metastases.

- Luthra et al. (2007)[12] demonstrated that tuberculous abscesses have higher ADC values compared to pyogenic abscesses, aiding in differentiation.

-We also noted that abscesses exhibit low ADC values, while tuberculomas showed no restriction, aligning with Luthra et al.'s findings regarding higher ADC values in tuberculous lesions.

- Heiserman et al. (1994)[13] provided early insights into using DWI alongside conventional MRI to differentiate cystic brain lesions.

-Our study also built on these early insights, showing how modern DWI techniques and ADC values can distinguish between a wider variety of intracranial lesions.

Our study found that DWI enhances the diagnostic accuracy of MRI in characterizing ring enhancing lesions by providing functional information based on water molecule diffusion within tissues. This technique allows for the calculation of apparent diffusion coefficient (ADC) values, which reflect tissue cellularity and integrity. Neoplastic lesions, such as high-grade gliomas and abscesses typically exhibit restricted diffusion and lower ADC values compared to other infective , inflammatory and demyelinating pathologies which show higher ADC values.
With the association of Conventional MRI and Diffusion weighted imaging we can easily differentiate the pathologies which can play crucial role for guiding appropriate treatment strategies.

The integration of DWI into the imaging protocol for ring-enhancing lesions (RELs) has significant implications in treatment response assessment also.
For instance, a decrease in ADC values post-treatment may indicate therapeutic efficacy in infectious lesions, whereas persistent restricted diffusion in neoplastic lesions may prompt consideration for adjuvant therapies or closer surveillance.

While histopathological confirmation remains the gold standard for definitive diagnosis, our study demonstrates a strong correlation between DWI findings and histopathological characteristics where available. This correlation underscores the reliability of DWI in predicting lesion behaviour and guiding clinical decisions, particularly in cases where tissue sampling is challenging.

Conclusion

- MRI with diffusion weighted imaging plays important role in characterizing the intracranial ring enhancing lesions.
- DWI provides critical and functional information through ADC values, along with conventional MRI sequences which depicts anatomical and enhancing characteristics.
- Diffusion weighted imaging and ADC values depicts combined utility in diagnostic accessibility and helps in patient management.

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