ISSN: 2457-0400
Impact Factor: 7.675

WORLD JOURNAL OF ADVANCE HEALTHCARE RESEARCH

www.wjahr.com

Volume: 10, Issue: 4
Page N. 235-241
Year: 2026

Original Article
Coden USA: WJAMA3

THE ROLE OF DIFFUSION WEIGHTED MR IMAGING IN RING ENHANCING BRAIN LESIONS

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Article Received: 05 March 2026 **Article Revised:** 25 March 2026 **Article Published:** 04 April 2026

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DOI: https://doi.org/10.5281/zenodo.19436050

How to cite this Article: [*1]Hussein Ketab Rhaif, [2]Shaymaa Hashim Mohammed, [3]Zeid Hamed Abbas Al-Marib, (2026). Hemodynamic Stability In Unilateral Versus Bilateral Spinal Anesthesia For Gynecological Surgery: A Comparative Study. World Journal of Advance Healthcare Research, 10(4), 235–241.

ABSTRACT

Background: Objective: to evaluate the role of diffusion weighted imaging in differentiating the cause of ring enhancing brain lesions. **Method:** Diffusion weighted imaging (DWI) was performed on 22 post-contrast brain MRI patients with ring-enhancing lesions. Diffusion restriction classified these lesions as malignant and abscess cavities. In the tumor group, primary tumors were diagnosed by histopathology obtained by surgery, but metastasis was diagnosed on the basis of clinical and radiological findings and had pathologically proven primary tumors. DWI sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy were calculated. T-tests compared mean ADC values of abscess and neoplastic lesions. **Results:** The diagnostic accuracy of DWI was 90.91 percent, with a sensitivity of 85.71 percent, specificity of 93.33 percent, positive predictive value of 85.71 percent, negative predictive value of 93.33 percent, and a sensitivity of 85.71 percent in distinguishing brain abscess from neoplastic brain lesions. The mean ADC value in the central cavity and wall of neoplastic lesions and brain abscesses was determined. **Conclusion:** Diffusion weighted imaging is a non-invasive method with high sensitivity and specificity which can help in differentiation of ring enhancing neoplastic lesions and brain abscesses. This modality should be read in conjunction with conventional imaging.

KEYWORDS: Ring enhancing brain lesions, diffusion weighted image, apparent diffusion coefficient.

INTRODUCTION

Ring-enhancing lesions on brain MRI represent a frequent and clinically important neuroimaging pattern with a broad differential diagnosis. Common causes include primary brain tumors (notably high-grade glioma), metastatic tumors, cerebral abscess, granuloma (e.g., tuberculoma), resolving hematoma, and subacute infarction; less common etiologies include thrombosed vascular malformations and demyelinating disease such as multiple sclerosis (MS), while uncommon causes include thrombosed aneurysm and selected tumors in specific settings (e.g., primary CNS lymphoma in AIDS).[1] These lesions often vary in size and are typically surrounded by perifocal vasogenic edema of variable degree, which may contribute substantially to symptoms and mass effect.[2] A major diagnostic challenge arises when differentiating infectious from neoplastic ring-enhancing lesions. Brain abscesses frequently appear as ring-enhancing masses on contrast-enhanced MRI, and cystic/necrotic neoplasms can closely mimic this appearance on conventional sequences.[3] Accurate distinction is crucial because management differs fundamentally: abscesses may be treated with targeted antibiotics and/or image-guided aspiration or drainage, whereas neoplastic lesions usually require biopsy, surgical resection when feasible, and systemic evaluation for metastasis.[4] Unfortunately, conventional CT and standard MRI may not reliably separate these entities in many cases, creating a persistent diagnostic dilemma.[4] Among neoplastic causes, brain metastases are common in adults and arise most often from lung, breast, renal cell carcinoma, colorectal adenocarcinoma, and melanoma; improved systemic cancer survival and advances in imaging have increased their detection.[5] Metastases typically localize at the gray–white junction with relatively sharp margins and edema that can be disproportionate to lesion size, and they may be solitary in a substantial proportion of patients despite the classic teaching of multiplicity.[7,8] High-grade gliomas—especially glioblastoma—are the most common primary malignant intracranial tumors in adults and characteristically show necrosis, heterogeneous enhancement, and extensive edema with infiltrative spread along white matter tracts.[8,9]

Advanced MRI techniques help address the limitations of conventional imaging. Diffusion-weighted imaging (DWI) measures water mobility, while the apparent diffusion coefficient (ADC) provides a quantitative estimate derived from signal changes across different b-values.[10,11] Because pus-filled abscess cavities often demonstrate restricted diffusion with low ADC—whereas necrotic or cystic tumor centers more commonly show higher ADC—DWI/ADC can improve diagnostic confidence, although restricted diffusion is not entirely specific and underlying mechanisms remain incompletely understood.[12,13] Consequently, integrating clinical context with contrast MRI and adjunct techniques such as DWI (and, when available, MR spectroscopy) is essential for accurate diagnosis and appropriate treatment planning.[14,15] The objective of this study was to evaluate the role of diffusion weighted MR imaging and ADC in distinguishing neoplastic from non-neoplastic ring enhancing brain lesions.

METHOD

This prospective study was conducted at Al-Imamain Al-Kadhimyain Medical City, Baghdad, between August 2014 and October 2015. Patients were referred from the Neuromedicine and Neurosurgery departments to the MRI unit of the Radiology department. A consultant radiologist specialized in neuroimaging selected cases based on imaging findings. Twenty-nine patients with ring-enhancing brain lesions were initially included; seven were excluded due to unavailable histopathological results or loss of follow-up. The final sample comprised 22 patients (14 males, 8 females) aged 12–69 years (mean age 43 ± 2.3 years). Inclusion criteria required absence of contraindications to MRI. Verbal informed consent was obtained from all participants. Histopathological confirmation was obtained surgically in most cystic intracranial space-occupying lesions. In cases of suspected brain abscess, diagnosis was confirmed by clinical presentation, laboratory findings, and radiological improvement following antibiotic therapy. MRI examinations were performed using a 1.5-Tesla Philips Achieva scanner with a head coil. Imaging parameters included 5-mm slice thickness, 1-mm interslice gap, 230 × 190 mm field of view, and a 256 × 161 matrix. Conventional sequences included axial T1-weighted spin-echo (TR/TE 596/15), axial T2-weighted fast spin-echo (3641/120), and sagittal T1-weighted images (596/15). All patients received intravenous gadolinium-DTPA contrast (0.1 mmol/kg). Diffusion-weighted imaging (DWI) was performed using a single-shot spin echo-planar sequence (TR/TE 5151/158). Diffusion gradients were applied in three orthogonal directions with b values of 0, 500, and 1000 s/mm². Apparent diffusion coefficient (ADC) maps were generated, and ADC values were measured from the center of each lesion using appropriately sized regions of interest to minimize volume averaging. Diffusion restriction was defined as hyperintensity on DWI with corresponding hypointensity on ADC maps. Lesions demonstrating restriction were classified as abscesses, while non-restricting lesions were considered neoplastic. Statistical analysis was performed using SPSS version 22. Student's t-test compared mean ADC values between groups. Receiver operating characteristic (ROC) analysis determined sensitivity, specificity, and optimal cutoff values. A p-value <0.05 was considered statistically significant.

RESULTS

The study group included twenty-two patients, the age of the patients ranges from 12 to 69 years mean (43 years). fourteen were male (64%) and eight were female (36 %) with male: female ratio equal to 1.75:1, as shown in table (1). Of the 22 cases, 7 (32%) lesions showed high diffusion signals with low ADC signals, indicating diffusion restriction, while 15 (68%) lesions showed low diffusion signals with high ADC signals, indicating non-restricted diffusion. Table 2 shows the results, as shown in table (1). On histopathology, 15 (68%) of 22 instances were neoplastic lesions and 7 (32%) were brain abscesses. Table 1 lists glioblastoma multiforme (9), metastasis (5), and heamangioblastoma (1) as malignant lesions. Six of seven brain abscesses (85.7%) showed diffusion restriction, but only one of 15 neoplastic lesions (6.6%) did. Diffusion-based assessment yielded 6 true positives, 1 false positive, 14 true negatives, and 1 false negative (table 1). Table (1) shows that DWI had a sensitivity of 85.71 %, specificity of 93.33 %, positive predictive value of 85.71 %, negative predictive value of 93.33 %, and diagnostic accuracy of 90.91 % in distinguishing brain abscess from neoplastic brain lesions:

Table (1): Demographic Data, Lesion Characteristics, and Diagnostic Performance of DWI (n = 22)

Category	Variable	Result
Demographics	Mean age (years)	43 ± 2.3
Demographics	Age range	12–69
Demographics	Male	14 (63.6%)
Demographics	Female	8 (36.4%)
Demographics	Male : Female ratio	1.75 : 1

Diffusion Pattern	Non-restricted diffusion	15 (68%)
Diffusion Pattern	Restricted diffusion	7 (32%)
Final Diagnosis	Neoplastic lesions (Total)	15 (68%)
Final Diagnosis	– Glioblastoma multiforme (GBM)	9 (41%)
Final Diagnosis	– Metastasis	5 (23%)
Final Diagnosis	– Hemangioblastoma	1 (4%)
Final Diagnosis	Abscesses	7 (32%)
Diagnostic Performance	True Positive (TP)	6
Diagnostic Performance	False Positive (FP)	1
Diagnostic Performance	True Negative (TN)	14
Diagnostic Performance	False Negative (FN)	1
Diagnostic Performance	Sensitivity	85.71%
Diagnostic Performance	Specificity	93.33%
Diagnostic Performance	Positive Predictive Value	85.71%
Diagnostic Performance	Negative Predictive Value	93.33%
Diagnostic Performance	Accuracy	90.91%

Abscesses demonstrated markedly lower ADC values compared with neoplastic lesions, reflecting restricted diffusion due to high viscosity and cellular content of purulent material. Neoplastic lesions showed higher ADC values, consistent with relatively free diffusion within cystic or necrotic tumor components. No overlap in ADC ranges was observed between abscesses and tumors in this study. These findings support the diagnostic value of DWI and ADC measurements in differentiating ring-enhancing brain lesions. As in table 2.

Table 2: Range of ADC Values in Neoplastic and Non-Neoplastic Ring-Enhancing Lesions.

Lesion Group	Tumor / Lesion Type	ADC Range ($\times 10^{-3}$ mm²/sec)
Neoplastic lesions	Glioblastoma multiforme (GBM)	1.89 – 2.19
Neoplastic lesions	Metastasis	2.29 – 2.86
Neoplastic lesions	Hemangioblastoma	2.95
Non-neoplastic lesions	Abscess	0.59 – 0.73

Mean ADC value in central cavity of neoplastic lesions 2.46 ± 1.37 x 10^{-3} mm^2/second and of brain abscesses are 0.65 ± 0.06 x 10^{-3} mm^2/second as shown in table (3).

Table (3): Comparison of ADC values between neoplastic and non-neoplastic lesions.

	Neoplastic N=15 Mean±SD	Non neoplastic N=7 Mean±SD	P value
ADC (x 10^{-3} mm^2/sec)	2.46±1.37	0.65 ± 0.06	0.0025

ADC shows 100% sensitivity and specificity with area under the curve 1.000, cutoff value 1.31 and significant p-value of less than 0.0001 in differentiation between neoplastic and non-neoplastic brain lesions. These relations clarified in (table 4) and (figure 1).

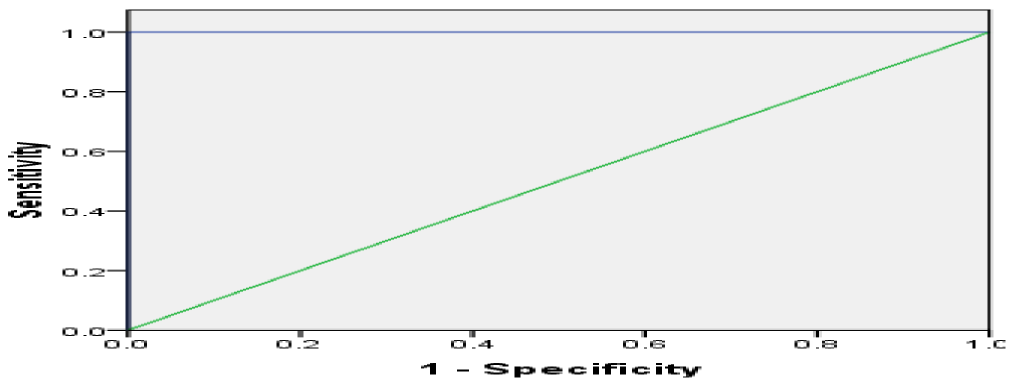


FIG (1): ROC curve for ADC of neoplastic and abscess.

Table (4): Sensitivity and specificity of ADC for neoplastic and abscess.

Cutoff value	Sensitivity	Specificity	Area under curve	P value
1.31	100%	100%	1.000	< 0.0001

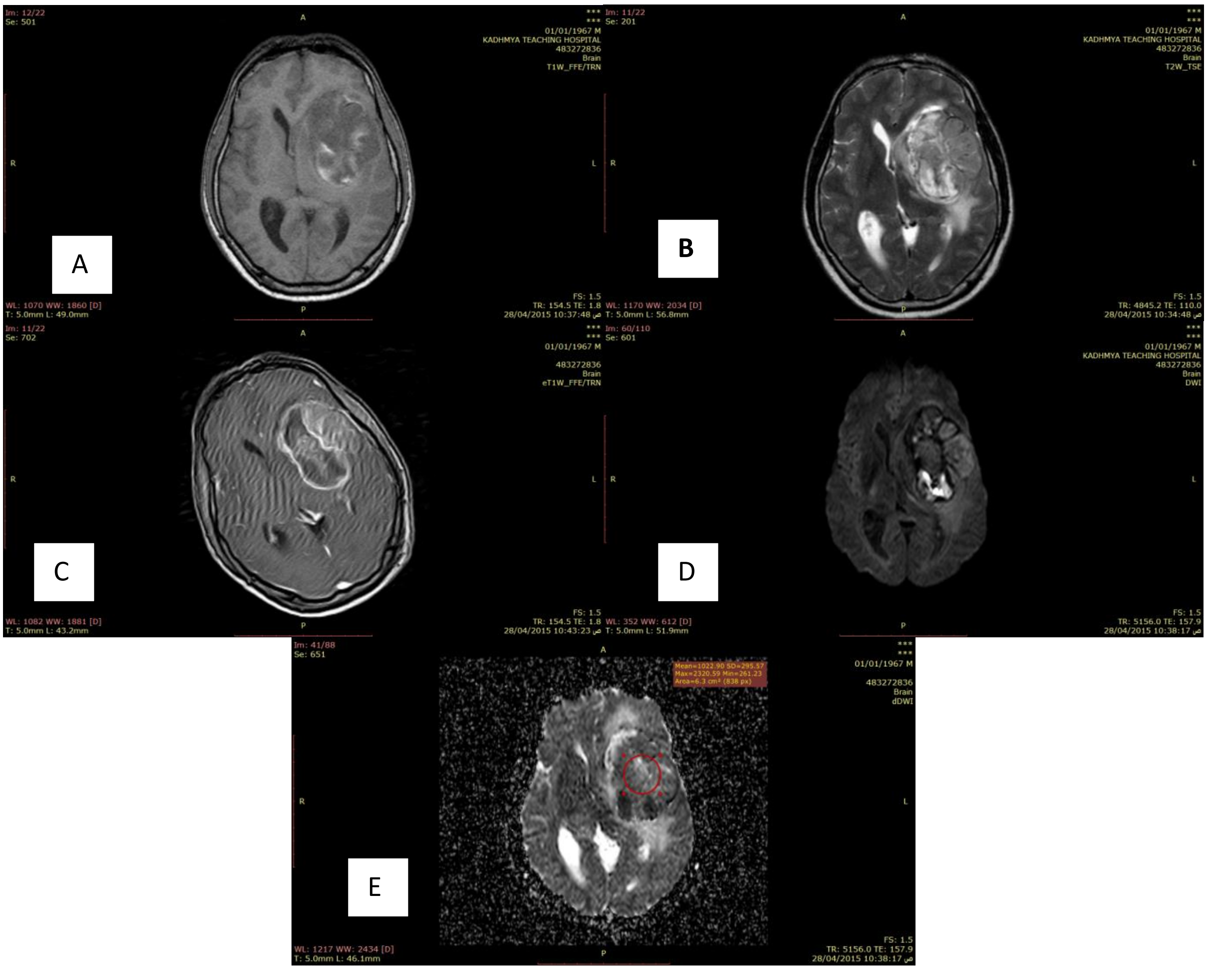
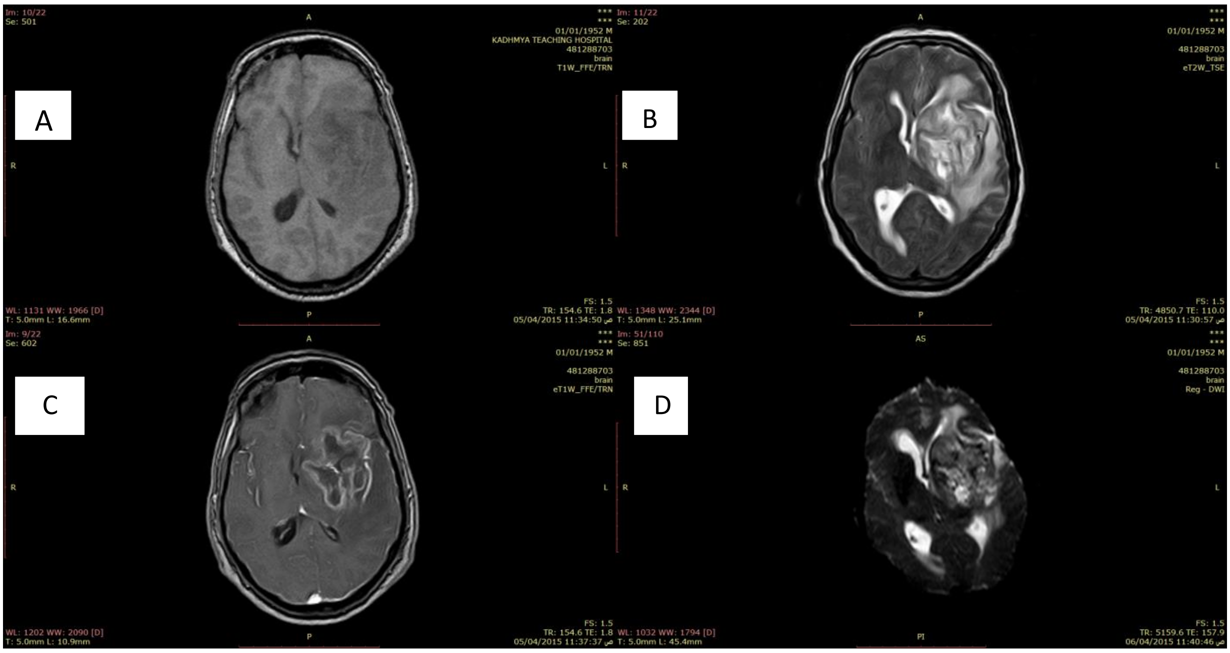


FIG (2): 47-year-old male patient with left parietal mass (A. T1 axial; B.T2 axial; C.T1 axial postcontrast; D. DWI; E. ADC) showing ring enhancement and non-restricted diffusion with maximal ADC values (2.32 x10-3) and biopsy-proven GBM.



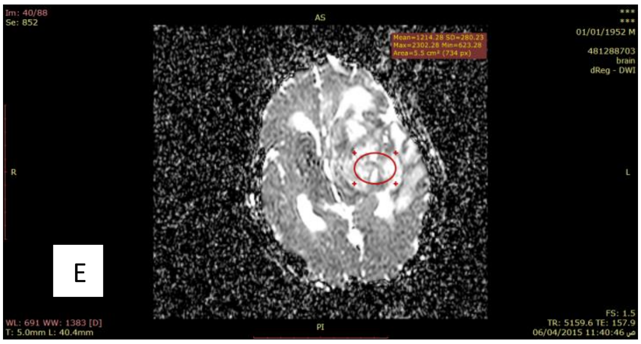


FIG (3): 63-year-old male patient with left parietal mass (A. T1 axial; B.T2 axial; C.T1 axial postcontrast; D. DWI; E. ADC) showing ring enhancement and non-restricted diffusion with maximal ADC values (2.30 x10-3) confirmed by biopsy as GBM.

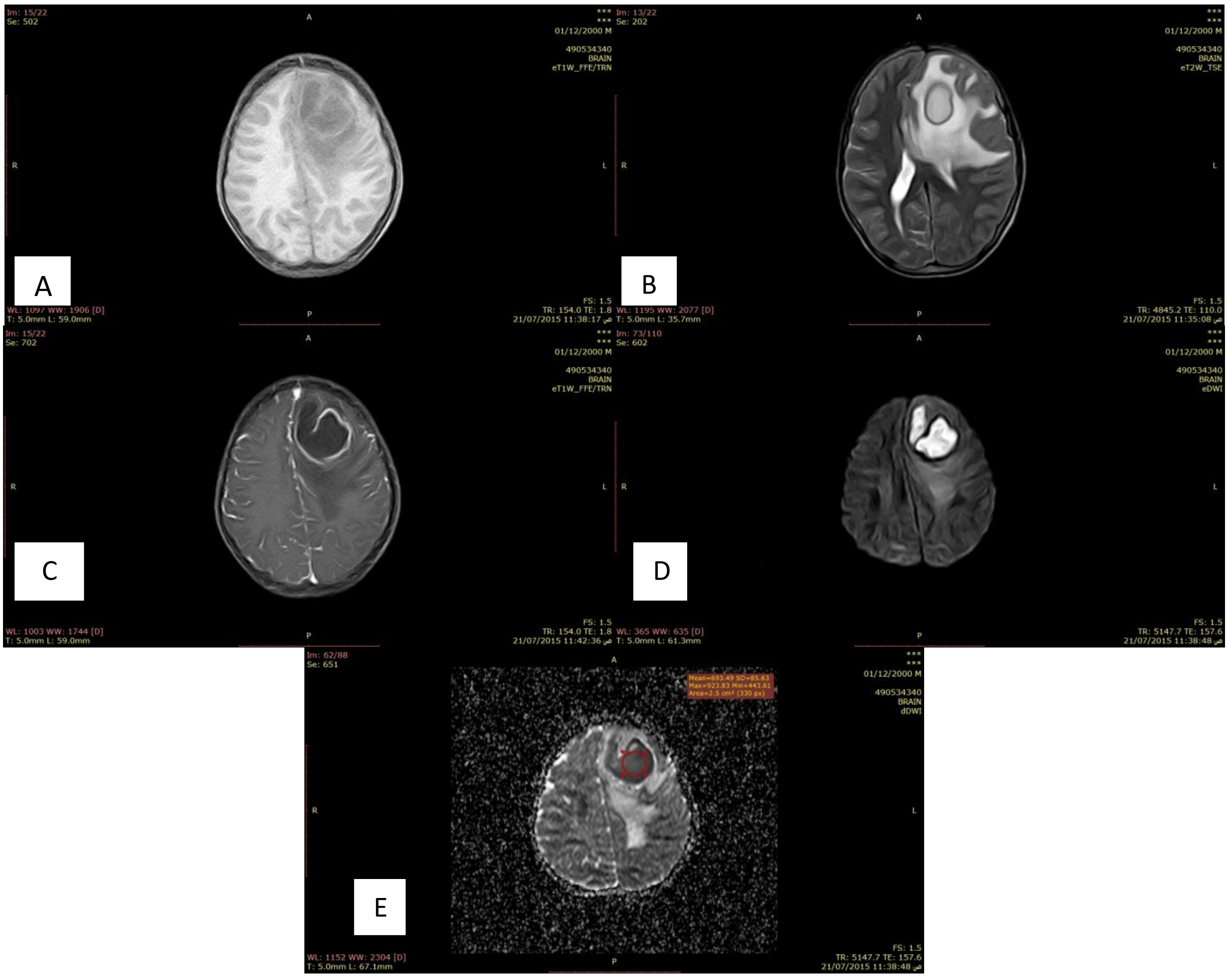


FIG (4): 15-year-old male patient with left parietal mass (A. T1 axial; B.T2 axial; C.T1 axial postcontrast; D. DWI; E. ADC) showing ring enhancement and restricted diffusion with maximal ADC values (0.92 x10-3) and biopsy-proven abscess.

DISCUSSION

Magnetic resonance imaging (MRI) is highly sensitive for detecting ring-enhancing brain lesions; however, distinguishing between neoplastic lesions and brain abscess remains a frequent diagnostic challenge. Advanced techniques such as magnetic resonance spectroscopy (MRS) and diffusion-weighted imaging (DWI) have been increasingly utilized to improve diagnostic accuracy. Although MRS can provide metabolic information, it is relatively time-consuming and less specific, particularly for lesions near the skull base where susceptibility artifacts may degrade image quality. In contrast, DWI is a rapid echo-planar technique that is practical in routine clinical settings and has shown considerable promise in differentiating ring-enhancing lesions.[16,17] Several previous studies have reported high diagnostic accuracy of DWI in distinguishing brain abscess from cystic or necrotic tumors. Nonetheless, occasional reports of diffusion restriction in neoplastic lesions and increased diffusion within abscess cavities have raised concerns regarding its absolute reliability.[18,19] In the present study, DWI demonstrated high sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. The mean apparent diffusion coefficient (ADC) value measured from the central cavity of abscesses was $0.65 \pm 0.06 \times 10^{-3}$ mm²/s, compared with $2.46 \pm 1.37 \times 10^{-3}$ mm²/s in neoplastic lesions, showing a statistically significant difference. These findings are consistent with prior literature. Lai and Wang et al. reported mean ADC values of $0.67 \pm 0.17 \times 10^{-3}$ mm²/s in abscesses and $2.73 \pm 0.34 \times 10^{-3}$ mm²/s in neoplastic lesions.[15] Similarly, Reddy and Gupta et al. documented mean ADC values of $0.9 \pm 0.13 \times 10^{-3}$ mm²/s in abscesses compared with $2.2 \pm 0.9 \times 10^{-3}$ mm²/s in non-abscess lesions.[20] Luthra and Prasad et al. also demonstrated low ADC values within pyogenic abscess cavities ($0.72 \pm 0.17 \times 10^{-3}$ mm²/s).[21] The restricted diffusion in abscesses is generally attributed to the high viscosity and cellularity of purulent material, which limits water molecule movement.[22] Despite the overall high diagnostic performance, one abscess case in this study did not demonstrate diffusion restriction. Similar rare cases have been described in the literature.[23,24] Possible explanations include variation in abscess viscosity, differences in protein concentration, partial treatment, or the evolutionary stage of the abscess. Follow-up imaging may reveal resolution of restriction after adequate therapy.[25] Conversely, one neoplastic lesion showed diffusion restriction, a phenomenon that has been debated in prior reports.[24,26] Increased cellular debris, elevated protein content, or intratumoral hemorrhage within necrotic tumor cavities may account for this finding. Overall, while DWI is highly valuable, correlation with clinical and conventional imaging findings remains essential.

CONCLUSION

Brain abscesses and necrotic tumors are difficult to distinguish on regular conventional imaging; thus fast identification is crucial since untreated brain abscesses can be fatal. Diffusion imaging helps improve health management by ring-enhancing brain lesions and distinguishing pyogenic brain abscesses from necrotic tumors. High sensitivity and specificity, this sequence should be utilized in addition to conventional imaging, not instead of histology.

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