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DIAGNOSTIC ACCURACY OF DWI VERSUS CONVENTIONAL MRI SEQUENCES IN DIFFERENTIATING BRAIN ABSCESS FROM NECROTIC TUMORS

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ABSTRACT

Background: Ring-enhancing intracranial lesions pose a frequent diagnostic dilemma on MRI, particularly in distinguishing brain abscesses from necrotic tumors, as these entities often share overlapping imaging features on conventional contrast-enhanced sequences. Accurate differentiation is essential because treatment strategies and prognoses differ markedly. Diffusion-weighted imaging (DWI) has been suggested to improve diagnostic confidence; however, its incremental value over conventional MRI sequences in routine practice remains to be clearly defined. **Objective:** To compare the diagnostic accuracy of diffusion-weighted imaging with conventional MRI sequences in differentiating brain abscesses from necrotic intracranial tumors. **Methods:** This retrospective diagnostic accuracy study will include patients with ring-enhancing intracranial lesions identified on brain MRI. Image interpretation will be performed in two stages: first using conventional MRI sequences alone (T1-weighted, T2-weighted, FLAIR, and post-contrast imaging), and subsequently with the addition of DWI and apparent diffusion coefficient (ADC) maps. Imaging diagnoses from both approaches will be compared with a reference standard established by histopathology, surgical findings, microbiological confirmation, or clinicoradiological follow-up. Sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy will be calculated and compared between the two imaging strategies. **Conclusion:** This study aims to determine whether DWI provides meaningful incremental diagnostic value beyond conventional MRI in evaluating ring-enhancing brain lesions, with potential implications for optimized imaging protocols and improved clinical decision-making.

KEYWORDS: Brain abscess, Necrotic tumor, Diffusion-weighted imaging, Magnetic resonance imaging.

INTRODUCTION

Ring enhancing intracranial lesions are arguably one of the biggest diagnostic challenges that daily clinical imaging practice poses to neuroradiologists. When a lesion presents as enhancing rings with central necrosis, the immediate differential diagnostic possibilities often remain restricted to a mere two entities that are quite different from one another, the brain abscess and necrotic tumor. Both entities, despite their similarities, fundamentally mandate diametrically opposite approaches and outcomes, should there be an erroneous approach in patient management. A brain abscess, as opposed to a necrotic tumor requires immediate treatment along with potential surgical interventions, as opposed to treatment modalities that an essentially necrotic tumor warrants.

T1-weighted, T2-weighted, FLAIR, and contrast enhanced imaging are all conventional MRI sequences that are commonly utilized in the assessment of ring enhancing lesions. However, there is significant overlap in the morphological features of abscesses and necrotic or cystic tumors on these sequences, which often limits diagnostic confidence when conventional imaging is used in isolation. Early studies identified this limitation and stressed the need for advanced imaging techniques to enhance lesion characterization.[4,18]

Diffusion weighted imaging (DWI) technique has been seen as an emerging potentially useful tool in such a scenario with initial studies reporting strongly compromised diffusion within the purulent core of abscesses compared with necrotic tumors.[1-3] Further studies confirmed the initial reports with abscesses showing higher signal intensity on DWI with lower values of the signal decay constant or apparent diffusion coefficient (ADC) as a result of the very viscous consistency of pus.[5-9] Thus, there has been increasing interest in the DWI technique as a tool to assist the diagnostic community in addressing the problem of diagnostic uncertainty.

subsequent studies have cautioned not to overemphasize the utility of restriction in the diffusion signal as an isolated criterion. Restricted signal in diffusion has been identified to be present in necrotic tumors like high-grade gliomas. Such observations have resulted in the apprehension that the usefulness of the profile on diffusion weighted images may not be entirely specific to abscess formation. Towards improving the diagnostic accuracy with the application of the technique, quantification of ADC values along with the utilization of elevated b-value evaluation as well as the integration with other advanced techniques have been attempted using MR spectroscopy. Nonetheless, meta-analyzed evidence emphasizes inhomogeneity in the application as well as the interpretation in the utilization of the approach.

Despite a large volume of literature supporting the role of DWI, one key practical question remains inadequately addressed: how much incremental diagnostic value does DWI really add beyond conventional MRI sequences in routine clinical practice? Many studies have evaluated DWI either alone or in combination with other advanced modalities, though relatively fewer have directly compared diagnostic performance before and after adding DWI to the standard MRI interpretation workflow.[4,7,15,16]

The aim of this article is therefore to compare the diagnostic accuracy of conventional MRI sequences alone to that of conventional MRI supplemented by DWI and ADC mapping in distinguishing brain abscesses from necrotic intracranial tumors. Building on prior research, this paper intends to assess the additional value brought by DWI as a supplement against established reference standards to clear up its everyday practical value in neuroimaging decision-making and to provide information about optimized imaging protocols for patients with ring-enhancing brain lesions.

METHOD

Study design

The study was a retrospective diagnostic accuracy study, and it was carried out to compare diagnostic efficacy of conventional MRI sequences with, and without, additional use of diffusion-weighted imaging and apparent diffusion coefficient in differentiating brain abscesses from necrotic intracranial tumors. As such, it was designed in accordance with conventional study layouts in diagnostic tests in medicine.

Data collection

A retrospective investigation was carried out based on brain MRI studies that were routinely collected from the radiology database over time. Patient information, as well as investigations such as laboratory studies and radiology studies, were reviewed from the electronic medical records. Prior to image analysis, patient information was made anonymous. The imaging studies carried out in the investigation were based on routine sequences involving conventional MRI as well as DWI and ADC quantifications.

Patient population and clinical assessment

Patients with ring-enhancing intracranial lesions on contrast-enhanced brain MRI scans with a definite diagnosis on a reference standard were included. Excluded were those with poor image data, poor follow-up data, or poor image quality. Clinical data such as age, sex, existence of fever on presentation, white blood cell count, diabetes mellitus, immunosuppression, and history of malignancies were used.

Imaging procedure and interpretation

The MRI scans included standard T1-weighted, T2-weighted sequences, FLAIR imaging, and post-contrast scans, as well as DW imaging and ADC sequences. Image interpretation was conducted in two parts: the first using standard MRI sequences alone, followed by image interpretation using a combination of standard MRI sequences and DW imaging/ADC sequences. The lesions were classified as either an abscess or necrotic tumor. Restricted diffusion was indicated by high signal intensity on DW imaging with corresponding low ADC values obtained using regions of interest within the tumor core.

Statistical Method

The statistical tests were conducted to compare clinical and imaging features between tumor and abscess groups. Mean ± standard deviation (SD) were used to summarize continuous variables, and compared with Wilcoxon rank-sum test. Reporting of categorical variables was done using number (percentage), and compared through Pearson's chi-squared test or Fisher's exact test, depending on which test was more appropriate. There was an examination of diagnostic categories of conventional imaging and diffusion weighted imaging (DWI) in comparison to groups. Independent predictors of abscess diagnosis were determined by using multivariate logistic regression, with reporting odds ratios (ORs) and 95% confidence intervals (CIs). The statistical significance was calculated as p less than 0.05.

RESULTS

A total of 140 patients were included in the analysis. The mean age of the cohort was 51 ± 17 years, and 78 patients (56%) were male. Diabetes was present in 22 patients (16%), immunocompromised status in 21 (15%), and a known history of malignancy in 18 (13%). Fever at presentation was documented in 33 patients (24%). The mean white blood cell count was 10.2 ± 4.0 $\times 10^9$ /L. Imaging measurements demonstrated a mean lesion size of 2.99 ± 1.18 cm and a mean ring thickness of 4.69 ± 1.76 mm. Multiloculated morphology was observed in 28 cases (20%), and rim irregularity in 52 cases (37%). The overall mean ADC value was 1.42 ± 0.55 $\times 10^{-3}$ mm²/s, and restricted diffusion was present in 60 patients (43%). Final diagnoses included 88 tumors (63%) and 52 abscesses (37%). Conventional imaging classified 83 lesions (59%) as tumor and 57 (41%) as abscess, whereas DWI classified 81 lesions (58%) as tumor and 59 (42%) as abscess (Table 1).

When stratified by final diagnosis, the tumor (n = 88) and abscess (n = 52) groups showed no significant difference in age (51 ± 16 vs 51 ± 18 years, $p > 0.9$) or sex distribution (female 41% vs 50%, $p = 0.4$). The prevalence of diabetes, immunocompromised status, known malignancy, and fever did not differ significantly between groups (all $p \geq 0.3$). The abscess group demonstrated a higher mean white blood cell count compared with the tumor group (11.8 ± 4.3 vs 9.2 ± 3.5 $\times 10^9$ /L, $p < 0.001$). Lesion size and ring thickness were comparable between groups ($p = 0.8$ and $p = 0.4$, respectively). Multiloculated lesions were observed more frequently in abscesses (29% vs 15%, $p = 0.073$), whereas rim irregularity was more common in tumors (43% vs 27%, $p = 0.081$). ADC values were significantly lower in abscesses (0.84 ± 0.24 vs 1.77 ± 0.35 $\times 10^{-3}$ mm²/s, $p < 0.001$). Restricted diffusion was present in 44 abscesses (85%) compared with 16 tumors (18%) ($p < 0.001$). Conventional imaging correctly classified 71 tumors (81%) and 40 abscesses (77%). DWI correctly classified 81 tumors (92%) and all 52 abscesses (100%) ($p < 0.001$) (Table 2).

Median ADC values with interquartile ranges further demonstrated separation between groups, with tumors showing higher ADC distributions and abscesses clustered in lower ADC ranges (Table 2, ADC distribution). This pattern remained consistent across subgroup analyses.

Multivariable logistic regression analysis demonstrated that restricted diffusion was independently associated with abscess diagnosis (OR 55.90, 95% CI 4.51–2,843, $p = 0.009$). Increasing ADC values were independently associated with tumor diagnosis ($p < 0.001$). Rim irregularity, fever, and known malignancy were not statistically significant after adjustment (all $p \geq 0.2$) (Table 3).

Model diagnostics demonstrated acceptable collinearity and stability, with variance inflation factors within acceptable limits and no evidence of multicollinearity. Performance metrics showed high classification accuracy, with DWI-based prediction demonstrating superior diagnostic performance compared with conventional imaging (performance metrics table).

Table 1: Baseline Clinical and Imaging Characteristics.

Variable	**N = 140**
Age (years), mean ± SD	51 ± 17
Sex, n (%)	
Female	62 (44%)
Male	78 (56%)
Diabetes, n (%)	22 (16%)
Immunocompromised, n (%)	21 (15%)
Known malignancy, n (%)	18 (13%)
Fever, n (%)	33 (24%)
WBC ($\times 10^9$ /L), mean ± SD	10.2 ± 4.0
Lesion size (cm), mean ± SD	2.99 ± 1.18
Ring thickness (mm), mean ± SD	4.69 ± 1.76
Multiloculated lesion, n (%)	28 (20%)
Rim irregularity, n (%)	52 (37%)
ADC mean ($\times 10^{-3}$ mm²/s), mean ± SD	1.42 ± 0.55
Restricted diffusion, n (%)	60 (43%)
True diagnosis, n (%)	
Tumor	88 (63%)
Abscess	52 (37%)
Conventional call, n (%)	
Tumor	83 (59%)
Abscess	57 (41%)
Diffusion-Weighted Imaging call, n (%)	
Tumor	81 (58%)

Abscess	59 (42%)
[1] Mean (SD); n (%)	

Table 2: Comparison of Clinical and Imaging Features Between Tumor and Abscess Groups.

Variable	Tumor (N = 88)	Abscess (N = 52)	P value[2]
Age (years), mean ± SD	51 ± 16	51 ± 18	>0.9
Sex, n (%)			0.4
Female	36 (41%)	26 (50%)	
Male	52 (59%)	26 (50%)	
Diabetes, n (%)	12 (14%)	10 (19%)	0.5
Immunocompromised, n (%)	11 (13%)	10 (19%)	0.4
Known malignancy, n (%)	14 (16%)	4 (7.7%)	0.3
Fever, n (%)	18 (20%)	15 (29%)	0.4
WBC ($\times 10^9$ /L), mean ± SD	9.2 ± 3.5	11.8 ± 4.3	**<0.001**
Lesion size (cm), mean ± SD	3.01 ± 1.25	2.96 ± 1.06	0.8
Ring thickness (mm), mean ± SD	4.79 ± 1.69	4.51 ± 1.86	0.4
Multiloculated lesion, n (%)	13 (15%)	15 (29%)	0.073
Rim irregularity, n (%)	38 (43%)	14 (27%)	0.081
ADC mean ($\times 10^{-3}$ mm²/s), mean ± SD	1.77 ± 0.35	0.84 ± 0.24	**<0.001**
Restricted diffusion, n (%)	16 (18%)	44 (85%)	**<0.001**
Conventional call, n (%)			**<0.001**
Tumor	71 (81%)	12 (23%)	
Abscess	17 (19%)	40 (77%)	
DWI call, n (%)			**<0.001**
Tumor	81 (92%)	0 (0%)	
Abscess	7 (8.0%)	52 (100%)	

[1] Mean (SD); n (%)
[2] Wilcoxon rank sum test; Pearson's Chi-squared test; Fisher's exact test

Table 3: Multivariable Logistic Regression Predictors of Abscess Diagnosis.

Predictor	Odds Ratio (OR)	95% CI		P value
		Lower	Upper	
Restricted diffusion				
No	—	—		
Yes	55.9	4.51	2843	**0.009**
ADC mean ($\times 10^{-3}$ mm²/s)	0.00	0.00	0.00	**<0.001**
Rim irregularity				
No	—	—		
Yes	0.39	0.03	3.51	0.4
Fever				
No	—	—		
Yes	0.11	0.00	2.05	0.2
Known malignancy				
No	—	—		
Yes	0.10	0.00	2.37	0.2

OR: Odds Ratio, CI: Confidence Interval

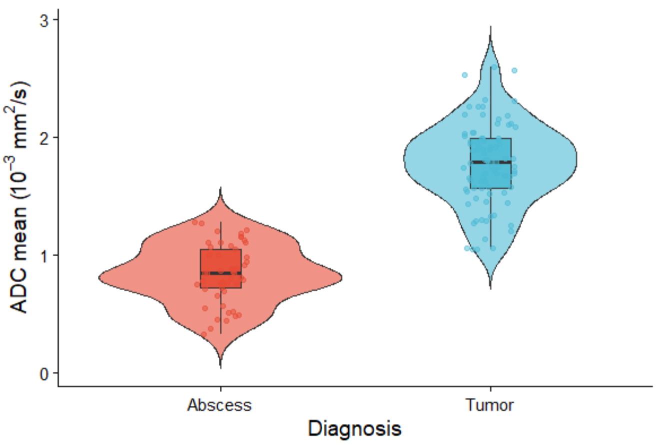

Figure 1: ADC Distribution by Diagnosis.

DISCUSSION

We investigated the incremental value of DWI beyond conventional MRI sequences for differentiation of brain abscesses from necrotic intracranial tumors. Our results indicate moderate diagnostic performance when relying on conventional MRI only, while DWI and ADC mapping provide added value for lesion classification, especially for brain abscesses. Based on these data, the practical question addressed by prior studies asking about the added value of DWI outside the research setting compared with standard imaging alone indeed has been answered.[4,7,15,17]

Morphological features on conventional MRI sequences, such as T1-weighted, T2-weighted, FLAIR, and post contrast imaging, have long been recognized as being limited by their overlapping features between abscesses and necrotic tumors.[4,18] In our cohort, lesion size and ring thickness failed to differ significantly between groups, consistent with prior reports.[4,18] both of whom showed significant morphological overlap on conventional sequences. Multiloculation tended to be more frequent in abscesses, with rim irregularity more common in tumors; however, these features failed to reach statistical significance. These findings further reinforce previous observations that morphology alone is not sufficiently specific.[4,16]

Diffusion-weighted imaging was the best discriminator in our investigations. Abscesses had significantly lower values of ADC and a much higher incidence of restricted diffusion compared to tumors. This is in very good agreement with the seminal studies by Ebisu et al.,[2] Kim et al.,[3] and Desprechins et al.,[1] which first established the much more marked restriction in the pus of abscesses. Subsequent studies have restated these findings, which were ascribed to the high viscosity of pus owing to the high cell content.[5,6,8,9,17] The average values of ADC in our case of abscesses are very close to those of.[6,5]

Most importantly, our study protocol enabled us to compare the classification results before and after incorporating DWI. According to our study, the classification results obtained with conventional MRI were 77% and 81% correct for abscesses and tumors, respectively, which were similar to those reported in the conventional imaging studies conducted before.[4,18] However, with the incorporation of DWI, the classification results improved significantly. It was found that 100% abscesses and 92% tumors were correctly classified, indicating significant improvements. This achievement was also reported by several other studies like,[7,15,16] who also found improvements in the classification ability with the incorporation of DWI.

Multivariable logistic regression analysis in our study has also emphasized the diagnostic significance of diffusion characteristics, whereby restricted diffusion was independently associated with abscess, whereas increasing ADC values independently correlated with tumor pathology. Such observations confirm previous pathological correlations performed by,[13] wherein diffusion restriction was shown to correlate with inflammatory cellularity rather than necrosis. What was also observed in our study was that clinical parameters such as fever, immunocompromised state, and known malignancy status were not independently associated, similar to other similar studies.[11,14] wherein limited discriminatory value was observed with regard to these clinical characteristics.

Although DWI has excellent diagnostic accuracy, our data confirm the preceding warnings regarding the reliance on DWI with restricted diffusion alone. DWI has indeed been seen in necrotic high-grade gliomas and metastases with the potential for misdiagnosing an abscess.[10,13] In this study, only a small percentage of lesions did have restricted diffusion, similar to the observations of Hartmann et al.,[10] and Gupta et al.,[13] emphasizing the importance of quantification of ADC in interpreting the MRI findings.[6,10,20]

These findings may also be understood within the context of meta-analytic studies. A recent meta-analysis[19] showed high levels of sensitivity and specificity for DWI in distinguishing abscesses and necrotic tumors. At the same time, it also pointed out discrepancies that have been observed with regard to ADC values, b values, and interpretation methods. Our results are consistent with the meta-analysis and have clinical relevance by simply implementing a two-step interpretation approach rather than a result obtained by only advanced imaging techniques.[19]

From a clinical point of view, regarding diagnostic efficacy, DWI also offers several benefits over other existing diagnostic modalities in terms of enhanced diagnostic efficacy, as shown in brain lesions, such as abscesses, where adequate early detection and differentiation of lesions, such as abscesses and necrotic tumors, by DWI, as reported by paper[8] and,[12] also relate to the enhanced diagnostic efficacy of DWI, in terms of identifying brain lesions, such as abscesses, in comparison to other existing diagnostic modalities.

In summary, the information obtained from this study showed that DWI provided significant incremental value in the differentiation of brain abscess from necrotic tumors, even compared with conventional MRI techniques. It was observed that with conventional MRI techniques, brain abscess could be differentiated from necrotic tumors, and therefore DWI and ADC map techniques significantly increase the level of precision and accuracy in decision-making, as recommended in existing DWI studies.[4,7,15,16,19]

CONCLUSION

Diffusion-weighted imaging significantly raises the diagnostic confidence of MRI for distinguishing brain abscesses from necrotic tumors. The addition of DWI and ADC mapping enhances lesion classification beyond conventional sequences, particularly for abscess detection, and supports their routine inclusion in MRI protocols for ring-enhancing intracranial lesions.

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