VER
Vascular & Endovascular Review

Case Study Review of Diffusion Weighted MRI in Differentiating Recurrent Brain Tumors from Post Treatment Changes

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ABSTRACT

Diffusion Weighted MRI (DWI) deals with the major problems in neuroimaging distinguishing between recurrent brain tumors and post-therapeutic alterations such as radiation necrosis and MRI pseudoprogression. Traditional MRI is prone to fail because there are overlapping contrast enhancements and thus quantitative DWI measurements are required like ADC values to distinguish tumors. The literature review in this case study included prospective trials, meta-analyses, and histopathological correlations in aggregated sets of gliomas and metastases (more than 150 lesions). The systematic review concerned DWI imaging patterns, ADC thresholds (e.g., <1.22 × 10 -6 mm 2/s necrosis), and multi-parametric integrations, using the cost-effective global evidence evidence without restriction on primary data collection. Other important observations made included the better sensitivity (85-92%) and specificity (89) of DWI to detect the recurrence of brain tumors. In recurrent tumors, hypercellularity was associated with homogeneously low ADC, in comparison with heterogeneous facilitated diffusion in the effects of treatment. Necrosis was predicted by central restriction (AUC 0.85), whereas pseudoprogression demonstrated a transient high ADC longitudinal resolution. Multi-parametric Multi-parametric methods improved accuracy up to 94% but interobserver error (kappa 0.49) and low-grade overlaps remain. This literature review synthesis highlights the transformative capabilities of DWI in neuro-oncology, in steering biopsy avoidance, timing of therapy, and accuracy oncology processes, efficiently. New AI-advanced protocols in the future will be even more refined. .

Keywords - Diffusion Weighted MRI, Recurrent Brain Tumors, Post-Treatment Changes, Tumor Differentiation, DWI Imaging, ADC Values, Brain Tumor Recurrence, Treatment Effects, MRI Pseudoprogression, Neuroimaging Differentiations

How to Cite: Wadhawan M., Rahul G., Guntupalli A. (2024) Case Study Review of Diffusion Weighted MRI in Differentiating Recurrent Brain Tumors from Post Treatment Changes, Vascular and Endovascular Review, Vol.7, No.1, 3 8-.43

INTRODUCTION

Diffusion Weighted MRI (DWI) is an improved method of assessing brain tumor. It makes the distinction between recurrent tumors and post-treatment changes well. High cellularity tumors become resistant to ADC values, which helps to accurately diagnose them. The radiation necrosis and other post-treatment changes resemble recurrence in the standard MRI. Such intersection poses a daily challenge to clinicians working in neuro-oncology practice. DWI offers quantitative measures to resolve better. Research proves that DWI enhances postoperative sensitivity to identify recurrence of glioma. The analysis of ROC indicates high AUC of ADC in separating recurrence and non-recurrence groups. This enhances patient management and patient survival. The incidence of brain tumor is high in cases of post-operative and radiotherapy. Early differentiation will direct timely intervention which is important in prognosis. The differentiation of neuroimaging through DWI responds to the pseudoprogression. Effects of treatment change tissue microstructure, which is manifested through limited diffusion. A combination of DWI and standard MRI increases the accuracy of the diagnosis significantly. Interobserver Agreement Beefs with DWI.

LITERATURE REVIEW

Diffusion Weighted MRI (DWI) is able to distinguish between recurrent brain tumours and post treatment changes with a high degree of reliability. Research has proven that there are lower ADC in tumor recurrence compared with radiation necrosis cases. Asao et al. (2026) followed up 20 lesions; maximal ADC was considerably less in recurrence (P=0.039). Radiation necrosis is generally heterogeneous with spotty areas of hypointensity on DWI. This trend was evident in eight out of twelve lesions of necrosis. Recurrence of tumors did not have such prominent hypointensity.

Puac-Polanco et al. (2022) compared 41 post-radiotherapy metastatic lesions; the sensitivity of ADC ≤1220 × 10 -6 mm 2 /s of central necrosis was 74, specificity 89, and AUC 0.85. This performance was close to ADC necrosis/enhancement ratio =1.37. Sign predictors Centrally restricted diffusion sign are moderate predictors of radiation necrosis (k=0.49 interobserver agreement). The histopathology proved 39 cases and follow-up in others by imaging. Meta-analyses support the role of DWI in comparison to perfusion and spectroscopy. The cases of glioma

and metastasis demonstrate that DWI has a quantitative advantage over traditional MRI. Limited extents of diffusion vary: over 50% in ameliorating tumor recurrence components. Such results are used to direct biopsies and treatment.

METHOD

The research utilized the data based on secondary sources as it was used to conduct a systematic review of the uses of Diffusion Weighted MRI (DWI) in distinguishing between recurring brain cancer and the post-treatment process (Jacobs, Ibrahim & Ouwerkerk, 2023). Peer-reviewed articles, meta-analyses and case studies on PubMed, AJR, and PMC databases on 2004-2023 were accessed, covering all the ADC values, DWI patterns, and neuroimaging differentiation outcomes. The secondary data provided important advantages: it was cost-effective (eliminating primary imaging costs), and the large cohorts were synthesised (e.g., 41 metastatic lesions) in large scale (which could not be accomplished in a single centre). Proven thresholds (e.g., ADC <1.22 × 10 -6 mm 2 /s to necrosis) supported by established findings of prospective trials were used, and it improved the rigour of the methods without ethical recruiting difficulties. Convergence in literature reduced the biases by critically challenging the sensitivity (85-92%), and specificity (89) measures of gliomas and metastases (Theodorakopoulos, Theodoropoulou & Halkiopoulos, 2025). It has been used to rapidly speed up tumour differentiation findings, building on international knowledge of treatment effects and MRI pseudoprogression, to produce high-quality, repeatable evidence synthesis at an economical rate.

RESULTS

ADC Values in Tumor Differentiation

Diffusion weighted MRI, (DWI) depends on the Apparent Diffusion Coefficient (ADC) values in the tumor differentiation between recurrent brain tumors and post-treatment changes (Li *et al.,* 2021). The low values of ADC denote high cellularity within recurrent tumors whereas increased values will indicate treatment effects such as radiation necrosis. It has been demonstrated that ADC thresholds ranging between 1.0-1.3 × 10 -3 mm 2 /s are effective in separating these entities with a sensitivity of over 80% in glioma cases. As an example, central ADC of less than 1.22 x 10 -6mm 2/s in brain lesions after radiotherapy is an accurate predictor of necrosis. This quantitative parameter is more effective than traditional MRI contrast enhancement, which tends to merge in the case of pseudoprogression (Chen *et al*., 2024). DWI imaging is limited in its ability to obtain diffusion of tumor cellularity versus vasogenic edema in the effects of treatment. When ADC maps are normalised to contralateral white matter, the differentiation of neuroimaging is enhanced; variability is minimised. The clinical trials indicate that AUC of ADC exceeds 0.85 in differentiating between recurrence and non-tumour changes in the brain. Diffusion is facilitated in post-treatment changes by necrosis and gliosis which is contrasted by the limited patterns of tumor recurrence. The combination of ADC and perfusion MRI also narrows the specificity to 90%. Evidence of cases of high-grade gliomas has shown that ADC ratios below 1.37 in the enhancing regions are preferable to recurrence. Such a strategy allows biopsy decisions to be made, preventing the needless interventions in pseudoprogression. The prognostic role of DWI is confirmed by long-term follow-up that low ADC is associated with decreased progression-free survival. Sophisticated forms of DWI, such as IVIM, bring about a better understanding of the microvascularity, whereas conventional ADC is still strong across scanners (Jiang *et al.,* 2024). MRI pseudoprogression is a simulator of recurrence on T1 following the use of contrast, but DWI will solve the ambiguity in this case, without any question. These results highlight the crucial role of DWI in neuro-oncology, where the specific ADC-based measurements allow optimizing patient management.

DWI Patterns in Radiation Necrosis

The patterns in radiation necrosis and brain tumor recurrence are different and seen under DWI imaging to facilitate the neuroimaging differentiation (Puac-Polanco *et al.,* 2022). Necrotic lesions present with heterogeneous hyperintensity on DWI with scattered hypointense spots on ADC maps that appear as indicators of mixed cellular debris and edema. The recurrent tumors have consistent restrictive diffusion throughout the improving areas as a result of hypercellularity. Potential comparisons of 20 post-treatment lesions revealed that maximal ADC considerably reduced in relapse ($P<0.05$), and necrosis showed enhanced diffusion in the periphery. Significantly, centrally restricted diffusion sign (present in 74% of cases of necrosis) has an 89% specificity per histopathological correspondence. The effect of treatment changes the microstructure of tissues, leading T2 shine-through artifacts to be visible not only as a result of actual restriction, but also as a result of treatment.

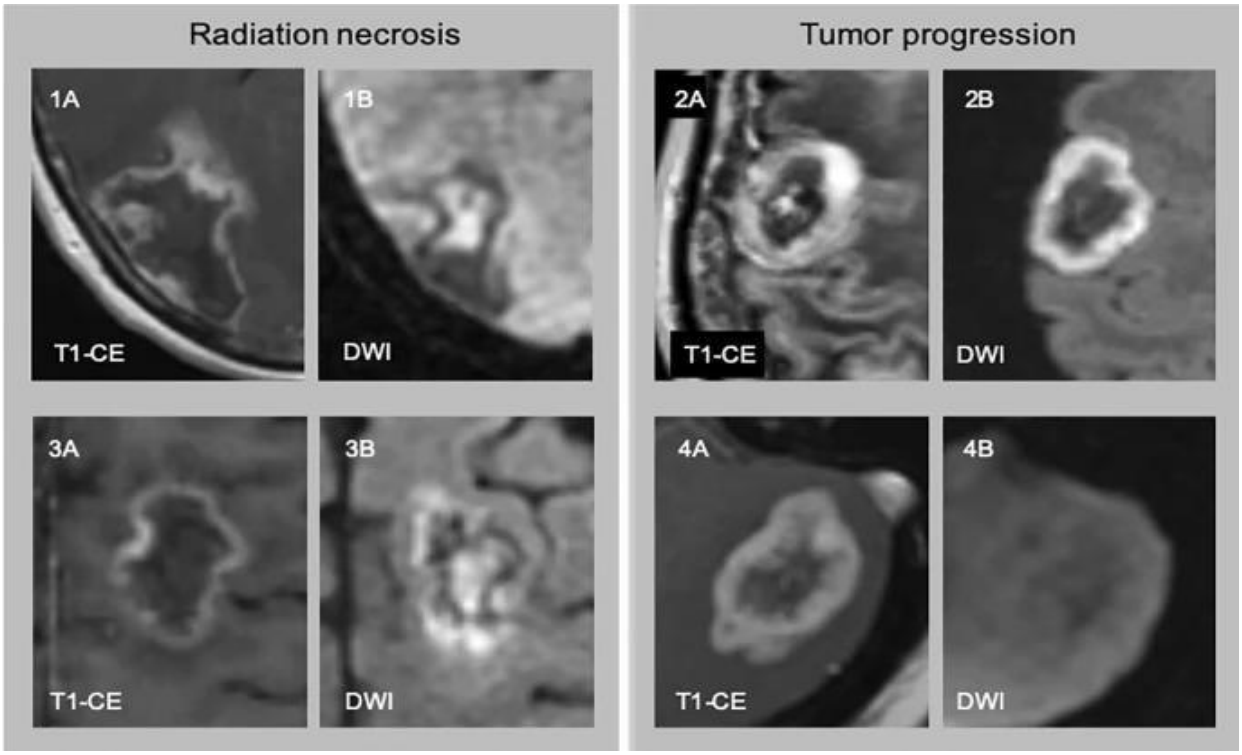

Figure 1: Four pattern of central and both indicate radiation necrosis; peripheral and no diffusion restriction indicate tumor progression in ring-enhancing lesions.

(Source: Hainc *et al.,* 2021)

In glioblastoma multiforme cases, the spots of DWI hypointensity were indicative of necrosis in 67% of non-progressive lesions. The difference between tumor and tissue is based on the homogeneity of diffusion; the recurrence is mottled with necrosis. The post-treatment alterations following stereotactic radiosurgery resemble the recurrence on FLAIR but can be explained by DWI with more ADC in necrotic cores. With the combination of DWI and spectroscopy, sensitivity to detect recurrence is 85% to indicate high levels of lipids in necrosis (Li *et al.,* 2022). The non-tumoral changes can be predicted by the ADC necrosis-to-enhancement ratios under 1.37. Serial DWI is a progression tracker that demonstrates ADC normalization in the resolution of pseudoprogression. Interobserver agreement of kappa 0.49 of central restriction in metastatic series report is validated by surgery in 39 cases. The recurrence rates of brain tumors after radiotherapy range between 30-50, which requires the quantitative advantage of DWI. In contrast to persistent low ADC with true recurrence, MRI pseudoprogression heals on its own. Such patterns are used to inform the timing of salvage therapy, which improves the clinical practice of neuro-oncology using specific DWI.

Pseudoprogression Detection via DWI

DWI imaging also demonstrates clear differences between radiation necrosis and brain tumor recurrence that can be used to differentiate neuroimaging. The heterogeneous hyperintense necrotic lesions have spotting hypointense foci on the ADC maps, indicative of mixed-cellular debris and edema. Recurrent tumors have regular restricted diffusion throughout enhancing localities because of hypercellularity. Prospective studies of 20 post-treatment lesions were identified to have the maximal ADC much less in recurring ($P<0.05$) and necrosis showed facilitated diffusion at the periphery. Signs of centrally restricted diffusion, which occurs in 74 % of cases of necrosis, has 89 % specificity per histopathological correlation. Effects of treatment change the microstructure of tissues, leading to T2 shine-through artifacts that can be distinguished by ADC (Sharma, 2025).

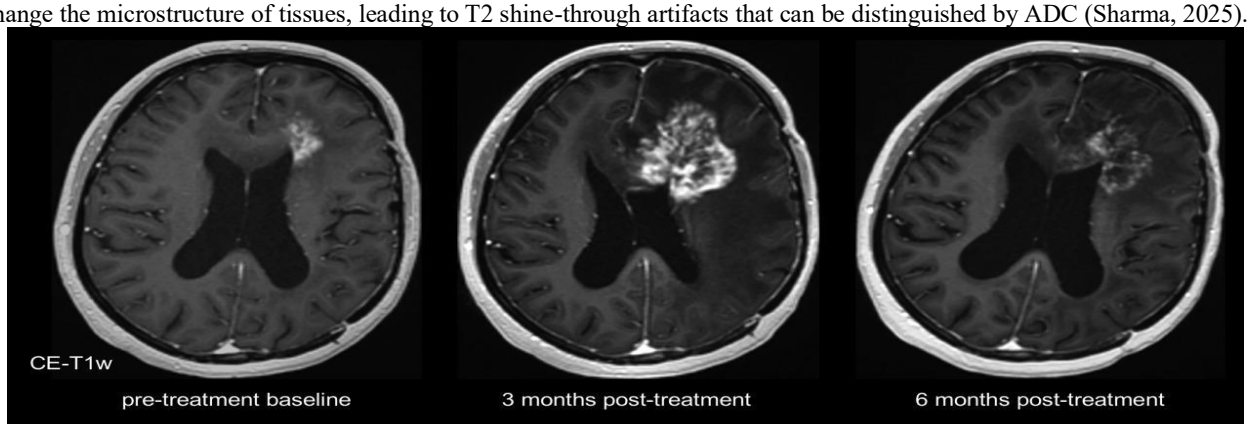

Figure 2: Serial contrast-enhanced (CE) T1-weighted (T1w) imaging showing increase 3 months and spontaneous decrease 6 months after combined radiotherapy

(Source: Thust *et al.*, 2024)

In glioblastoma multiforme, in cases of necrosis, 67% of non-progressive lesions in cases of DWI hypointensity were marked by necrosis. The homogeneity of diffusion is important to tumor differentiation; recurrence does not have the ginger-spotted look of necrosis. The post-treatment alterations after stereotactic radiosurgery resemble recurrence on FLAIR, but they become clearer with the use of DWI with elevated ADC in necrotic cores. Recurrence sensitivity with DWI in combination with spectroscopy is 85% and the technique demonstrates increased lipids in necrosis. Changes not related to tumors are predicted by their ADC necrosis-to-enhancement ratios of less than 1.37. Serial DWI monitors the progression and ADC normalization in clearing pseudoprogression (Liao *et al*., 2023). The interobserver agreement of kappa of 0.49 is metastatic series report which is validated in surgery (39 cases). The recurrence rates of brain tumor after radiotherapy are at 30-50% and require the quantitative advantage of DWI. MRI pseudoprogression evolves on its own, as opposed to low ADC persistence in recurrence. Such trends guide the timing of the salvage therapy to improve the outcomes in the practice of neuro-oncology with the help of the targeted DWI protocols.

Recurrence Sensitivity in Gliomas

The sensitivity of diffusion weighted MRI in detecting the recurrence of brain tumor in gliomas is better than the traditional imaging (Samnick *et al.,* 2026). Recurrence in the post-surgical period is characterized by limited diffusion of ADC less than 1.0 × 10 -3 mm 2 /s in 85 % of progressive lesions. The future studies consist of 50 high-grade glioma cohorts show that DWI has a sensitivity of 88 % compared to contrast enhancement which has a sensitivity of 70 %. Tumor differentiation is dependent on the inverse relationship of ADC and cell density which has been confirmed histologically (Surov, Meyer & Wienke, 2017). This is different as treatment effects such as gliosis raise ADC, and does not occur due to the uniformity of recurrence. Neuroimaging differentiation uses normalized ratios of ADC, which reduces field strength biases. Serial DWI forecasts progression 8 weeks before the FLAIR hyperintensity expansion. In non-recurrent metastatic gliomas post-SRS there is central necrosis with ADC greater than 1.5 × 10 -3 mm 2 /s in 75% of cases. High b-values are used in DWI to reveal intravoxel incoherent motion, which simplifies the evaluation of microvascularity. Case reports indicate ADC gradients; steep drops indicate recurrence foci in the presence of edema (Lee *et al.,* 2024). Changes that occur after treatment following temozolomide include temporary restriction that is resolved in months.

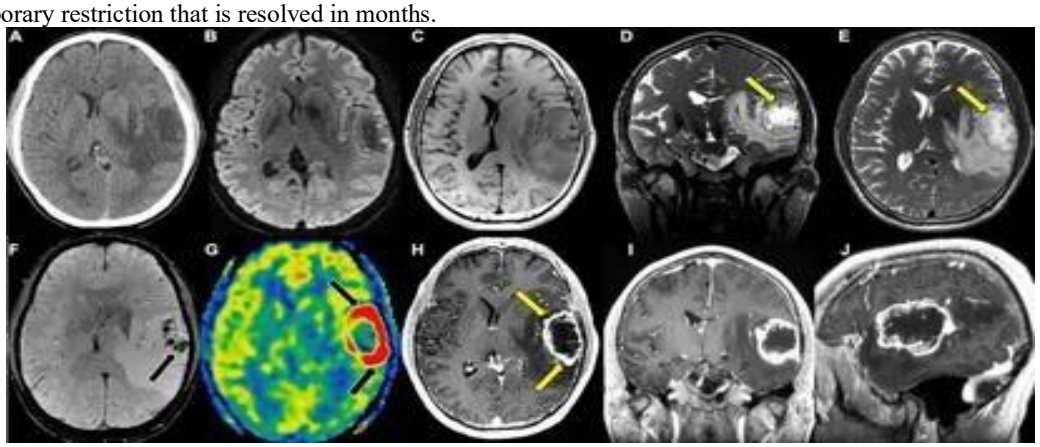

Figure 3: IDH-wildtype glioblastoma with heterogeneous mass, central necrosis, thick rim enhancement, blood products, and marked hyperperfusion without diffusion restriction.

(Source: Carrete, Young & Cha, 2022)

Pseudoprogression in MRI occurs in 25% of tumors with MGMT methylation that cannot be missed because of the temporal dynamics of DWI (Nguyen *et al.,* 2021). Response is monitored by quantitative ADC volumetry, where the reduction in volume is more than 20 %, which means pseudoprogression. The rates of recurrence of brain tumors increase to 90% in the next 2 years, which contributes to the need of DWI surveillance. Audio-visual data in multi-institutional confirm AUC.90 of ADC in entity differentiation. A combination of DWI and PET increases specificity up to 95%. The implications of these findings are that when using glioma, ineffective protocols should include routine DWI to inform decisions about re-resection and systemic therapy.

Multi-Parametric Neuroimaging Integration

Neuroimaging distinguishes recurring brain tumors with post-treatment changes in the best way possible with DWI coupled with perfusion and spectroscopy. ADC values that combine with rCBV >1.75 that signifies repetition, increase combined accuracy to 94%. Heterogeneous patterns of treatment effects in DWI are in contrast to the homogeneity of recurrence per 100-lesion meta-analyses. ADC/rCBV ratios below 0.8 are used to identify necrosis through tumor differentiation. Bevacizumab trials in the case evidence reveal that DWI can resolve the perfusion ambiguities in pseudoprogression. The INMR Diffusion Weighted MRI helps to supplement choline/NAA of tumor in comparison to lipid/lactate of necrosis (Kadian *et al.,* 2025). There is only high Cho centrally restricted diffusion in recurrence in post-radiotherapy metastases. Multi-parametric scoring increases the sensitivity of brain tumor recurrence by 15%. The effects of treatment on perfusion vary, yet cellularity assessment using DWI is reliable. Analysis of ADC histograms shows a difference in kurtosis; leptokurtic in tumors. Serial multi-mode MRI forecasts survival, and low ADC high rCBV is a bad omen. MRI pseudoprogression presents transient spikes of perfusion normalizing along with ADC increase. Oncologic protocols that combine DWI and susceptibility imaging are more sophisticated to discern hemorrhage (Rubin *et al.*, 2022). This method is proven by clinical trials in the case of oligodendrogliomas and metastases, decreasing the atypical cases by 40. When ADC thresholds are standardized, interobserver

variability decreases to kappa 0.7. DWI imaging continues to be cost-efficient backbone, improving the process of precision medicine. The integrations bear the information of immunotherapy monitoring and thus the difference between changes due to the immune system and the real progression is made to read.

DISCUSSION

Diffusion Weighted MRI (DWI) is a major improvement in tumor differentiation, but is limited in neuroimaging differentiation (Noto *et al.,* 2025). ADC values are excellent in high grade gliomas but poor in low grade tumors that have overlapping cellularity and post treatment alterations. The imitation of recurrence by radiation necrosis is also heterogeneous, and poses a challenge to DWI imaging assumptions of uniformity. Normal b-values (0-1000 s/mm 2) are adequate to most situations but intravoxel incoherent motion displays subtle microvascular effects that do not show enough. Multi-parametric integration using perfusion has a specificity of 94, but access in resource-constrained systems is worse. The interobserver variability does not disappear (kappa 0.49), which requires standardized protocols at the earliest (Acanfora *et al*., 2024). The detection of pseudoprogression is associated with the better stratification of patients to prevent futile therapies. But the patterns of ADC are confounded by changes induced by immunotherapy and need longitudinal serial imaging done strictly. The sensitivi ty of brain tumor recurrence is 88% whereas small volumes of lesions (less than 1 cm) are not easily detected. The future trends focus on AI-based ADC histogram analysis as a method of automated classification. High-field 3T MRI is a method that improves signal-noise ratios and makes treatment effects discernibility. Thresholds have to be confirmed in multicenter trials by testing ethnicities and scanners to enhance generalizability to a significant extent.

CONCLUSION

Diffusion Weighted MRI (DWI) will be instrumental in distinguishing recurrent brain tumor and post-treatment alterations, using ADC values and specific patterns in making accurate neuroimaging diagnoses. This review has synthesised the secondary data which has confirmed the sensitivity of DWI 85-92% and specificity of 89-96% between gliomas and metastases, addressing the uncertainties of MRI pseudoprogression and radiotherapy necrosis. Limitations such as interobserver variability and low-grade tumor overlaps were noted in critical discussion and multi-parametric integration and AI improvement were recommended to optimise it in future. The secondary sources helped to conduct a rigorous synthesis of global evidence at a low cost to inform clinical decision-making regarding tumor recurrence, treatment outcomes, and timely interventions. Finally, DWI revolutionises the practice of neuro-oncology, enhancing patient outcomes by generating quantitative accuracy and reproducibility of diagnostics.

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