Magnetic resonance imaging for glioblastoma recurrence diagnosis

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MRI plays a key role in the evaluation of post-treatment changes, both in the immediate post-operative period and during follow-up. There are many different treatment's lines and many different neuroradiological findings according to the treatment chosen and the clinical timepoint at which MRI is performed. Structural MRI is often insufficient to correctly interpret and define treatment-related changes. For that, advanced MRI modalities, including perfusion and permeability imaging, diffusion tensor imaging, and magnetic resonance spectroscopy, are increasingly utilized in clinical practice to characterize treatment effects more comprehensively [1)]

The purpose of a study was to evaluate the diagnostic performance of single-parameter, unimodal and bimodal magnetic resonance imaging (MRI) in differentiating tumor recurrence (TR) from radiation necrosis (RN) in patients with glioblastoma (GBM) after treatment using diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), dynamic susceptibility contrast enhancement-perfusion weighted imaging (DSC-PWI), and proton magnetic resonance spectroscopy (Proton magnetic resonance spectroscopic imaging).

Materials and methods: Patients with histologically proven GBM who underwent surgical intervention followed by chemoradiotherapy and developed a new, progressively enhanced lesion on follow-up MRI were included in our study. Subsequently, DWI, DTI, DSC-PWI, and Proton magnetic resonance spectroscopic imaging were performed. Then, these patients underwent a second surgical operation or follow-up MRI to prove TR or RN. MRI metrics include apparent diffusion coefficient (ADC) and relative ADC (rADC) values derived from DWI; fractional anisotropy (FA), axial diffusion coefficient (DA) and radial diffusion coefficient (DR) values derived from DTI; and relative cerebral blood volume (rCBV) and relative cerebral blood flow (rCBF) derived from DSC-PWI. Spectral metabolites such as choline (Cho), creatine (Cr), N-acetylaspartate (NAA), lactate (Lac), and lipids (Lip) were derived from MRS, and the ratios of these metabolites were calculated, including Cho/NAA, Cho/Cr, NAA/Cr, Lac/Cr, and Lip/Cr. These indices were compared between the TR group and RN group, and the receiver operating characteristic (ROC) curve was used to evaluate the performance in distinguishing TR from

RN by using single-parameter, unimodal and bimodal MRI.

Results: There were significant differences between the TR and RN groups in terms of ADC ($p = 0.001$), rADC ($p < 0.001$), FA ($p = 0.001$), DA ($p = 0.003$), DR ($p = 0.003$), rCBV ($p < 0.001$), rCBF ($p < 0.001$), Cho/NAA ($p < 0.001$), Lac/Cr ($p < 0.001$) and Lip/Cr ($p < 0.001$). ROC analysis suggested that rCBV, MRS, and DSC + MRS were the optimal single-parameter, unimodal, and bimodal MRI classifiers for distinguishing TR from RN, with AUC values of 0.909, 0.940, and 0.994, respectively.

Conclusion: The combination of parameters based on multiparametric MRI in the region of enhanced lesions is a valuable noninvasive tool for discriminating TR from RN. [2)]

Magnetic Resonance Imaging (MRI) is a crucial imaging modality for the diagnosis and monitoring of glioblastoma recurrence.

Structural Imaging:

T1-weighted Image: Provides anatomical details and can help identify the location and extent of the tumor.

T2-weighted Image: Shows areas of edema and helps distinguish between tumor and surrounding brain tissue.

Contrast-Enhanced Imaging:

Gadolinium-enhanced T1-weighted Imaging: Glioblastomas often exhibit increased vascular permeability. The administration of a contrast agent (gadolinium) enhances visualization of tumor-associated blood-brain barrier disruption. New or enhancing lesions on post-contrast images may indicate tumor recurrence.

Perfusion Imaging:

Dynamic Susceptibility Weighted Contrast-Enhanced (DSC) Perfusion Imaging: Measures blood flow and microvascular permeability. Increased perfusion in a specific area may suggest tumor recurrence.

Diffusion-Weighted Imaging (DWI):

Apparent Diffusion Coefficient (ADC) Maps: Assess the movement of water molecules in tissues. Tumor recurrence may present with restricted diffusion due to increased cellularity.

Functional MRI (fMRI):

Blood Oxygen Level Dependent (BOLD) Imaging: Maps brain activity and can help identify areas involved in functional processes. It is used in some cases to locate critical brain regions before surgery. Serial Imaging:

Comparative Studies Over Time: Comparing current MRI findings with previous scans allows for the assessment of changes, including the appearance of new lesions or growth of existing ones. Advanced Imaging Techniques:

MRI Perfusion and Diffusion Tensor Imaging (DTI): These techniques can provide more detailed

information about blood flow and white matter tracts, helping in the evaluation of tumor extent and its impact on surrounding structures. Susceptibility-Weighted Imaging (SWI):

Detection of Microhemorrhages: SWI can identify microhemorrhages within or around the tumor, which may be indicative of recurrent disease. MRI is non-invasive and serves as a cornerstone in the diagnosis and follow-up of glioblastoma patients. It provides valuable information for treatment planning, including surgical resection, radiation therapy, and chemotherapy. The combination of different MRI sequences and advanced imaging techniques enhances the sensitivity and specificity of glioblastoma recurrence detection. Additionally, close collaboration between neuroimaging specialists, neurosurgeons, and oncologists is essential for accurate diagnosis and appropriate management

Diffusion-weighted magnetic resonance imaging

Diffusion-weighted magnetic resonance imaging in glioblastoma recurrence diagnosis.

Proton magnetic resonance spectroscopic imaging

Proton magnetic resonance spectroscopic imaging in glioblastoma recurrence diagnosis.

T2-weighted magnetic resonance imaging sequence

Relative cerebral blood volume, as measured by T2 weighted image dynamic susceptibility contrast MRI imaging, represents the most robust and widely used perfusion MR imaging metric in neurooncology.

FLAIR

An increase in the FLAIR signal of the fluid within the resection cavity is described as a highly specific and early sign for tumor recurrence in gliomas.

An increase in FLAIR signal of the fluid within the resection cavity might be a highly specific and early sign of local tumor recurrence/tumor progression also for brain metastases. [3].

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see Intravoxel incoherent motion

Visually imperceptible imaging patterns discovered via multiparametric pattern analysis methods (T1, T1-gadolinium, T2-weighted, T2-weighted fluid-attenuated inversion recovery, diffusion tensor imaging, and dynamic susceptibility contrast-enhanced magnetic resonance images) were found to estimate the extent of infiltration and location of future tumor recurrence, paving the way for improved targeted treatment [4].

1)

Martucci M, Russo R, Giordano C, Schiarelli C, D'Apolito G, Tuzza L, Lisi F, Ferrara G, Schimperna F, Vassalli S, Calandrelli R, Gaudino S. Advanced Magnetic Resonance Imaging in the Evaluation of Treated Glioblastoma: A Pictorial Essay. Cancers (Basel). 2023 Jul 26;15(15):3790. doi: 10.3390/cancers15153790. PMID: 37568606; PMCID: PMC10417432.

2)

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3)

Bette S, Gempt J, Wiestler B, Huber T, Specht H, Meyer B, Zimmer C, Kirschke JS, Boeckh-Behrens T. Increase in FLAIR Signal of the Fluid Within the Resection Cavity as Early Recurrence Marker: Also Valid for Brain Metastases? Rofo. 2017 Jan;189(1):63-70. doi: 10.1055/s-0042-119686. PubMed PMID: 28002859.

4)

Akbari H, Macyszyn L, Da X, Bilello M, Wolf RL, Martinez-Lage M, Biros G, Alonso-Basanta M, O'Rourke DM, Davatzikos C. Imaging Surrogates of Infiltration Obtained Via Multiparametric Imaging Pattern Analysis Predict Subsequent Location of Recurrence of Glioblastoma. Neurosurgery. 2016 Apr;78(4):572-80. doi: 10.1227/NEU.0000000000001202. PubMed PMID: 26813856.